Repco AUTO TECH

# 2017.3

AUTO-TECH masterclass

Training for Master Technicians

High Tech
Vibration Diagnostics

Dual Mass Flywheels

4WD Switching and Control

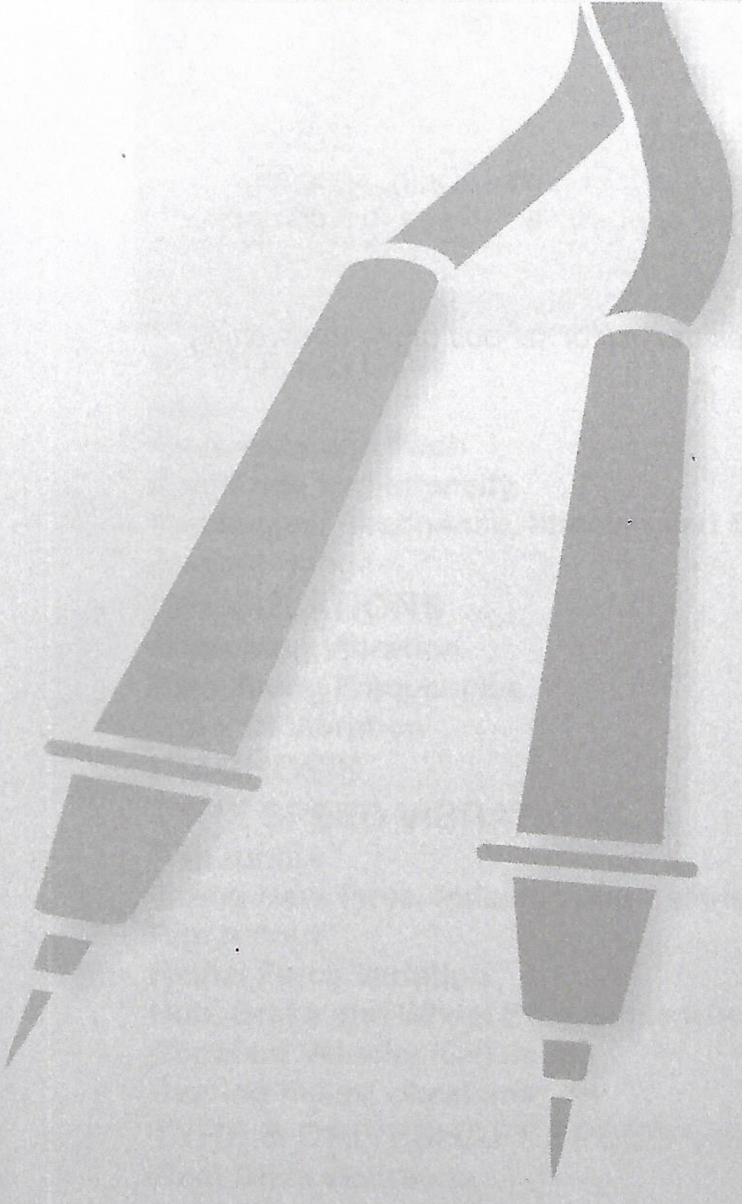
Concentric Clutch Cylinders

Pull Type Clutches

Two Wire Hall Sensors

# CRITICAL DRIVELINE DIAGNOSTICS

AUTO-TECH
MASTERCLASS
Training for Master Technicians



- High Tech Vibration Diagnostics
- Dual Mass Flywheels
- 4WD Switching and Control
- Concentric Clutch Cylinders
- Pull Type Clutches
- Two Wire Hall Sensors

## 2017.3

# CRITICAL DRIVELINE DIAGNOSTICS

### Section i

# Vibration Diagnostics

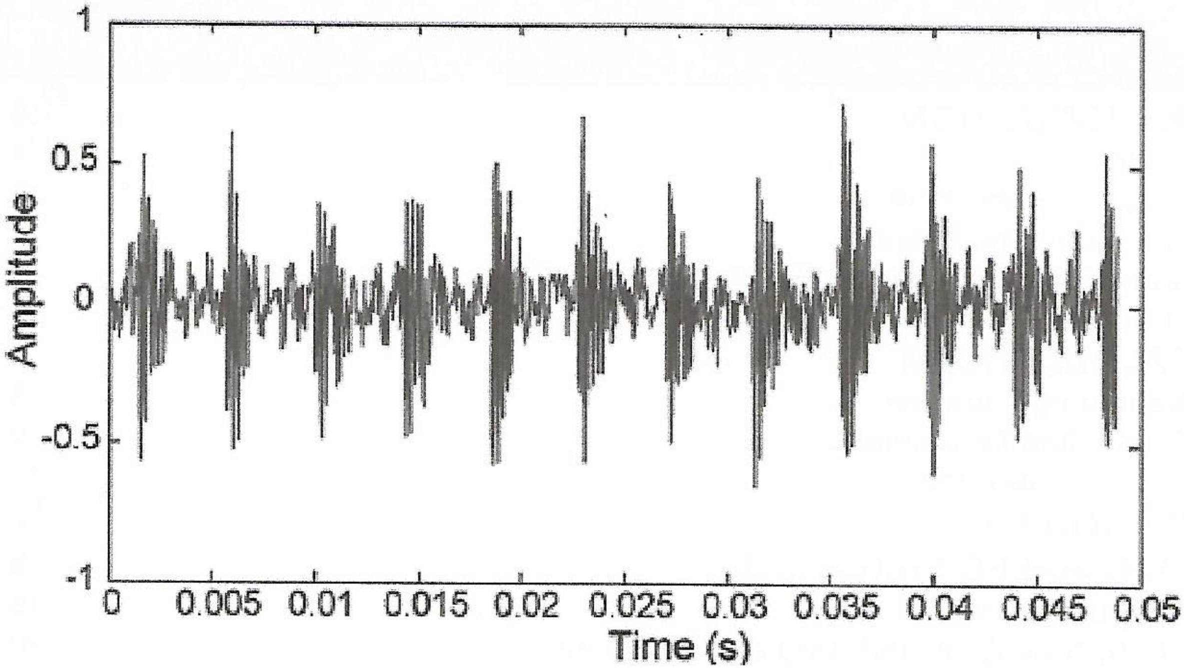
## CONTENTS

INTRODUCTION 4
Cycle 4
Frequency and Pitch 5
Amplitude and Intensity 6
Harmonics, Resonance, Phasing and Beating 7
Audible Range 8
CALCULATIONS 9
Measuring Vibration 9
Calculating Frequencies 9
Order of Vibration 11
DIAGNOSIS 12
TYRE SPEED VIBRATIONS 19
Tyre runout 19
Fitting New Tyres, Indexing and Balancing 20
Rim runout 21
Radial Force Variation 22
Hub, Brake and Wheel Stud Circle Runout 23
Constant Velocity (CV) Joints 26
Bearing failure vibrations 28
TYRE & DRIVESHAFT SPEED VIBRATIONS 29
Final Drive vibrations 29
DRIVESHAFT SPEED VIBRATIONS 30
Driveshaft Runout 30
Differential Pinion runout 31
Transmission/Transfer output runout and Driveshaft Indexing 32
Universal Joints, Engine and Transmission Mountings 33
Driveshaft Phasing (U-Joint shafts) 34
Driveshaft Angle (U-Joint shafts) 36
Driveshaft Flex Couplings 38
ENGINE SPEED VIBRATIONS 39
Normal Engine Vibrations, Engine and Trans Mountings 39
Exhaust Mountings, Flexible Hoses and Cables, Misfire and Camshafts 40
Harmonic Balancer, Flywheel, Clutch, Driveplate and Torque Converter 41
Other vibrations 42
SPECIAL SERVICE TOOLS 43

# INTRODUCTION

Vibration is the cyclic or oscillating movement of an object, which usually produces a noise. The noise may come from the vibration source, or the vibration may transfer to another point where the sound is generated. Having a knowledge of how vibrations are generated in the driveline will reduce diagnostic time and incorrect diagnosis.

Vibrations and the associated noise are produced in waves

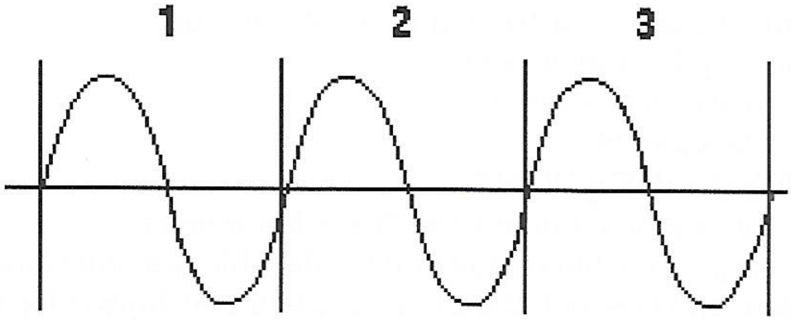


*Typical waveform showing vibration*

Similar to electrical sine waves, vibrational waves have a cycle, frequency and amplitude. In addition, audible waves have pitch and intensity.

**Cycle**

One cycle is usually defined by measuring from the point that the upward stroke of the waveform passes the midpoint to the next upward pass of the midpoint. However, this is not a requirement and the cycle can be measured from any point to the same point of the next cycle.



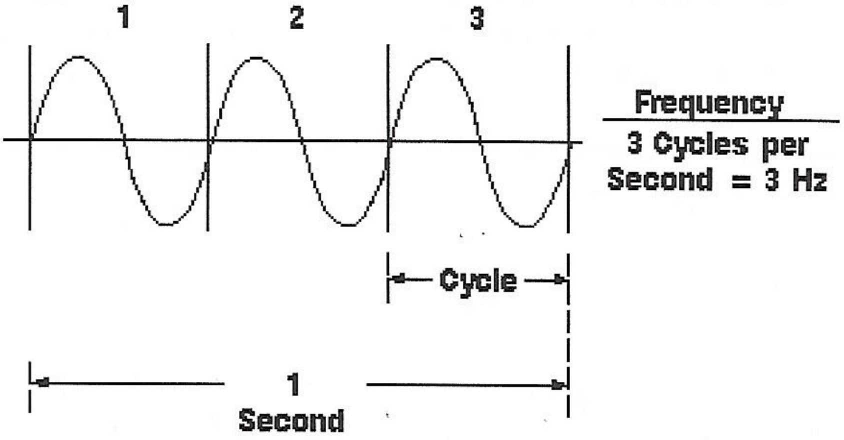
*Waveform showing three complete cycles*

Important.

## INTRODUCTION continued...

### Frequency

The frequency is the number of cycles per second and is expressed as Hertz (Hz).



*Waveform showing three complete cycles in 1 second*

*Note:*

*Low frequency vibrations (5 to 20Hz) are usually tyre speed related issue. The frequency will vary with vehicle speed.*

*Medium frequency vibrations (20 to 50Hz) are usually driveshaft related issues. The frequency will vary with vehicle speed.*

*High frequency vibrations (50 to 100Hz) are usually engine related. The frequency will vary with engine speed.*

### Pitch

Pitch is the quality of the sound and is directly proportional to the frequency. High Hz equals High Pitch.

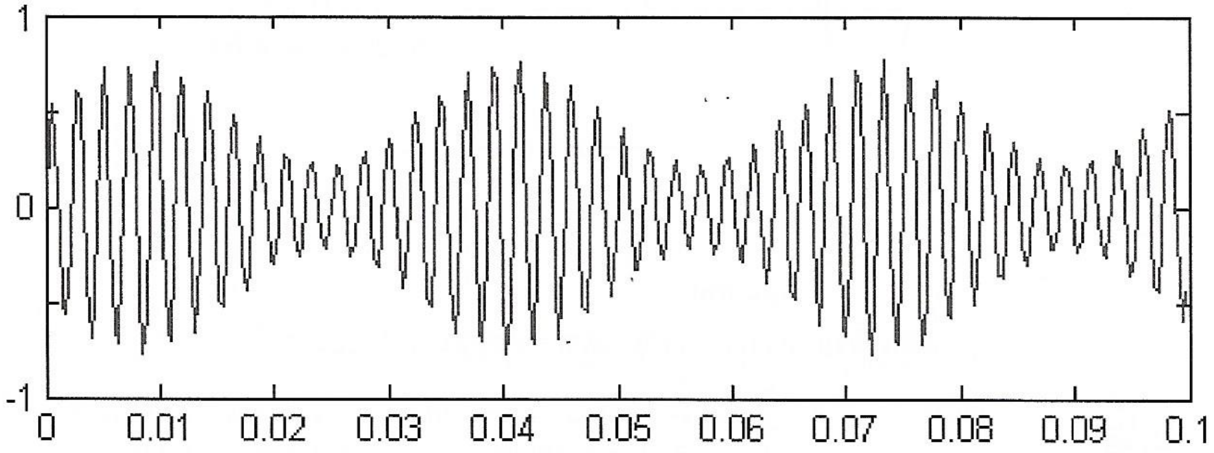
① Noise can express itself in a certain area but not be the cause of the problem.

② order of vibration refers to no. of vibrations per revolution.

## INTRODUCTION continued...

### Amplitude

The amplitude refers to the amount of energy produced by the vibration. This is shown in the waveform by the distance between the peak and its opposing trough. Amplitude is measured in G-Force (g) but due to the amplitude these figures are usually displayed as milli-G's (mg).



*Waveform showing a vibration with a fixed frequency at varying amplitude*

### Intensity

The Intensity of a sound refers to the amount which is directly proportional to the Amplitude. Intensity is measured in decibels (dB). 160dB is the safe limit for human ears.

### Harmonics

Harmonics describes the relationship between 2 or more vibrations. A balance shaft in an engine works by counteracting one vibration with an opposing vibration. Harmonics can be heard in two forms:

- Resonance
- Phasing

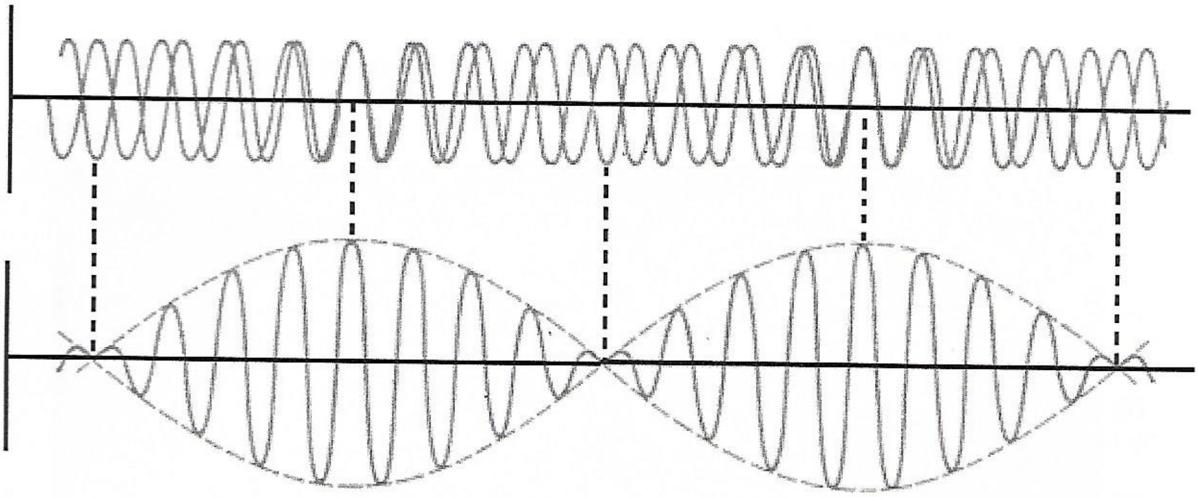
### Resonance

Resonance occurs when two frequencies are equal and in time.
All objects have a natural frequency and any object that is disturbed will resonate at its natural frequency. The natural frequency of a vehicle suspension (passenger car) is usually set between 10Hz and 15Hz and is controlled by adjusting the mass and/or spring stiffness. Resonance occurs when the frequency of a vibration acting upon an object matches its natural frequency resulting in amplification.

Resonance is the reason that an out of balance wheel will be more noticeable at a certain speed than at others.

## INTRODUCTION continued...

**Phasing and Beating**
When two or more different frequencies occurring simultaneously shift between being in sync (phased), to out of sync and opposing. Causing a noise to increase and decrease in amplitude, this is called Beating.



*The top waveform illustrates two vibrations at slightly different frequencies.*
*The bottom waveform shows the overall amplitude increase and decrease as the phasing varies.*

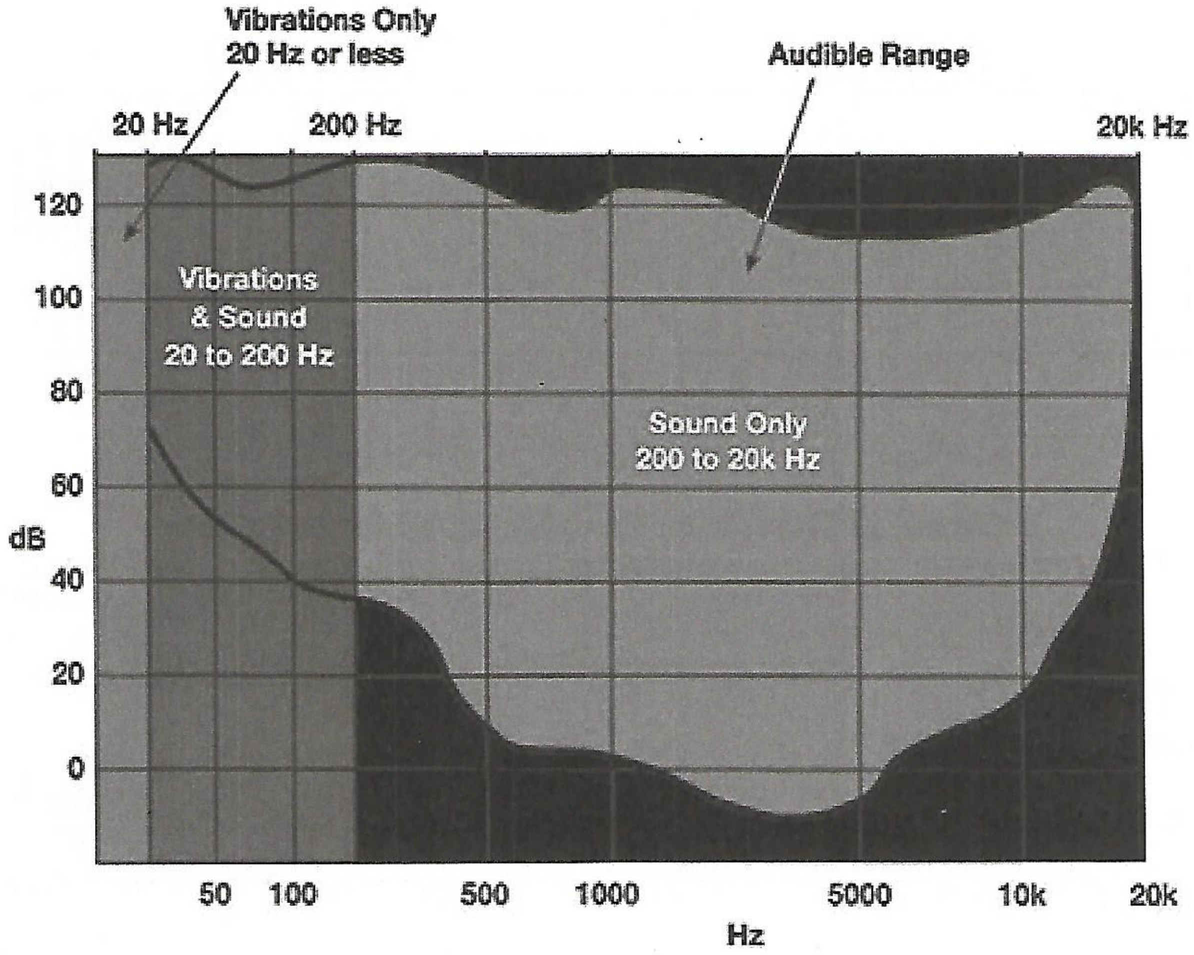
* Frequency is the most important factor to use in vibrations.

* Tyre balance come in @ differnt speeds due to wheel lining up & not lining up with other vibrations in car.

## INTRODUCTION continued...

### Audible Range

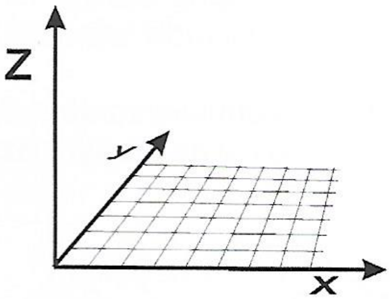
The audible range for humans varies from 20Hz to 20kHz, however it is largely recognised that the average range is closer to 100Hz to 15kHz. Only very low frequencies (below 200Hz) can be felt as a vibration.



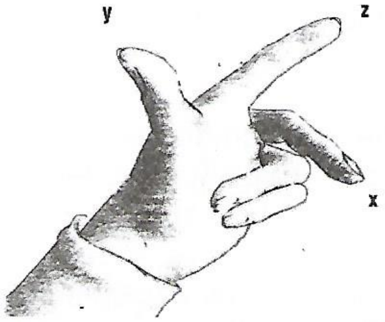
# CALCULATIONS

## Measuring Vibration

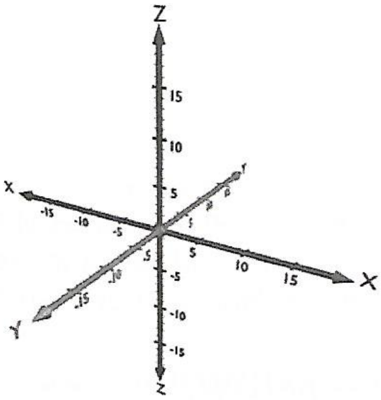
Measurements should be taken on three axis X, Y and Z. In noise and vibration diagnostics these axis will be represented in both positive and negative attributes giving a total of 6 directions of measurement.



Basic x-y-z axis



Hand rule



Actual axis of measurement

## Calculating Frequencies

In order to associate a vibration with its source you first need to calculate what frequencies the individual components are turning at. As frequencies are measured in Hertz (Hz) it is necessary to calculate the Hz for the individual components.

Engine Speed to Engine Hz

Engine speed is usually given in Revolutions Per Minute (RPM) and Hz is Cycles per Second. So dividing RPM by the number of seconds in one minute (60) will give you the Engine Hz.

*RPM / 60 = Engine Hz*

*Example: 3000RPM / 60 = 50Hz*

Engine Hz to Driveshaft Hz

The relationship between engine Hz and Driveshaft Hz is directly proportional to the gear ratio between the two. In older vehicles where a gear ratio of 1:1 was usually found this is very simple. Modern transmissions, the increased popularity of automatic transmissions, multiple overdrives, transfer cases in 4WD all make this conversion more difficult to use on the road.

TRANS Gear ratio.

*Engine Hz / Gear Ratio = Driveshaft Hz*

*Example of 0.88:1 overdrive: 50Hz / 0.88 = 56.8Hz*

Note: *Converting Vehicle Speed to Driveshaft Hz is usually simpler!*

## CALCULATIONS continued...

Driveshaft Hz to Tyre Hz

The relationship between Driveshaft Hz and Tyre Hz is directly proportional to the final drive ratio. Unlike the transmission, the final drive is a fixed ratio making the equation more practical to apply.

↙ Diff

*Driveshaft Hz / Final Drive ratio = Tyre Hz*

*Example: 56.8Hz / 4.1 = 13.9Hz*

Vehicle Speed to Tyre Hz

Depending on the cause of the vibration, the available vehicle information or the equipment used to diagnose the vibration; it is often easier to calculate the Tyre Hz from the Vehicle Speed (km/h).

To do this we need to convert km/h into metres per second (m/s) this is done by dividing by a factor of 3.6 (3600 seconds per hour / 1000 metres per kilometre).

You will also need the tyre circumference, this can be done by measuring the circumference or by multiplying the tyre diameter in metres (d) by Pi (π or 3.142).

*(km/h / 3.6) / (d x π) = Tyre Hz*

*(100km/h / 3.6) / (0.63m x 3.142) = Tyre Hz*

*27.78 / 2 = 13.9Hz*

Tyre Hz to Driveshaft Hz

The relationship between Tyre Hz and Driveshaft Hz is directly proportional to the final drive ratio.

*Tyre Hz x Final Drive ratio = Driveshaft Hz*

*Example: 13.9Hz / 4.1 = 56.8Hz*

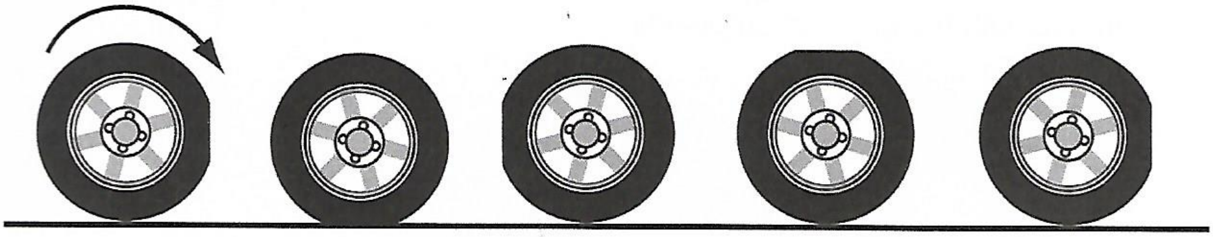
Note - Important out of Balance component can ever produce a first order vibration.

## CALCULATIONS continued...

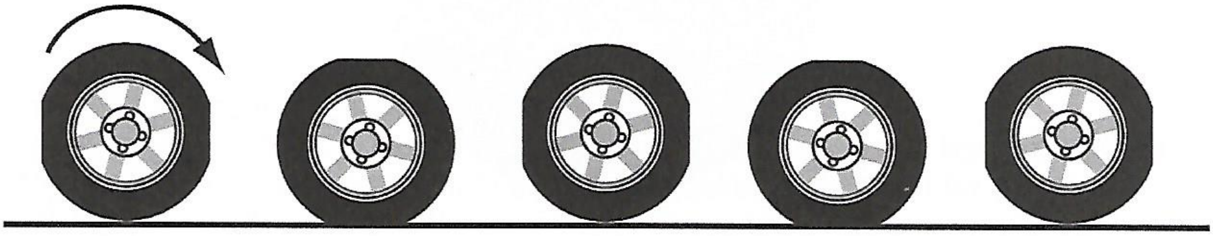
**Order of Vibration**
The order of a vibration refers to the number of vibrations per revolution. This is important in diagnosing vibrations because the frequency of the vibration will vary but the order of vibration will not.

The crankshaft of an engine converts the downward force of the piston into a rotational force (torque), in doing so it naturally creates a vibration. An Otto Cycle four cylinder engine will create a second order vibration, while a six cylinder creates third order vibration and an eight cylinder produces a fourth order vibration, etc...

More simply, a single flat spot on a tyre will create a first order vibration while two opposing flat spots will create a second order vibration.



*First Order Vibration*



*Second Order Vibration*

*Note:*

*One of the most important fundamentals to understand is that an out of balance component can only ever produce a first order vibration.*

*But if that sounds too simple... it is!*

*The first order is relevant to the turning component not the monitored component.*
*Example: An out of balance camshaft phaser turning at half the crankshaft speed (0.5 order).*

*Using the examples on the previous 2 pages; a vehicle with a vibration of 113.6Hz at 100km/h would be a second order driveshaft related issue.*

* Place meter on drivers seat close to Tunnel.

# DIAGNOSIS

## Vibration Diagnosis Equipment

There have been a number of tools that been designed to measure vibrations.

Note: *When trying to convert the Hz measured from the vibration to RPM, you need to factor in the Order of Vibration to tool is reacting to!*
*(See: Normal Engine Vibrations on Page 39)*

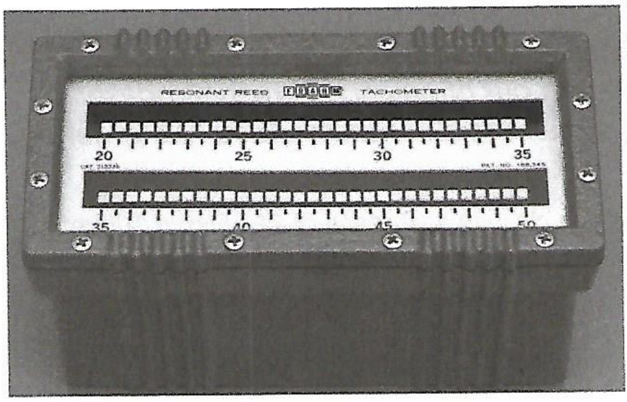
*Hz x Order of Vibration x 60 = RPM*

### Sirometer

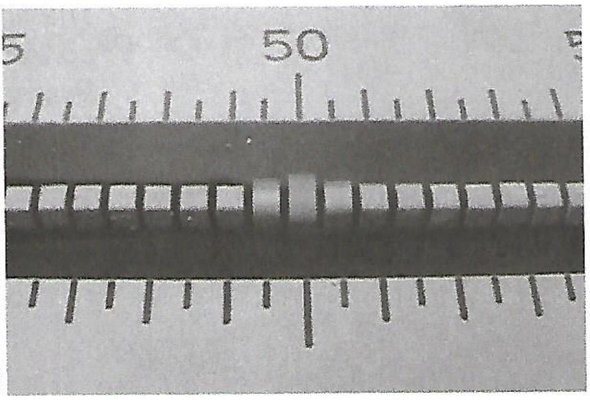
A sirometer (also known as a vibration tachometer) uses a torsion spring attached to a rotating gauge. As the spring extends it varies the natural frequency of the extended spring. By finding the point where the spring vibrates the most will equal the vibration with the greatest amplitude.

### Resonant Reed Tachometer

Reed tachometers are available in various sizes (number of reeds) and various frequency ranges depending on application. They can also have values of Hertz (Hz), Revolutions per Minute (RPM) and Cycles Per Second (CPM). The main advantage over the Sirometer is there is no dialling in maximum amplitude. The frequency is identified by observing which reed is vibrating the most. If two vibrations are concurrent, both will vibrate simultaneously.



*Resonant Reed Tachometer*

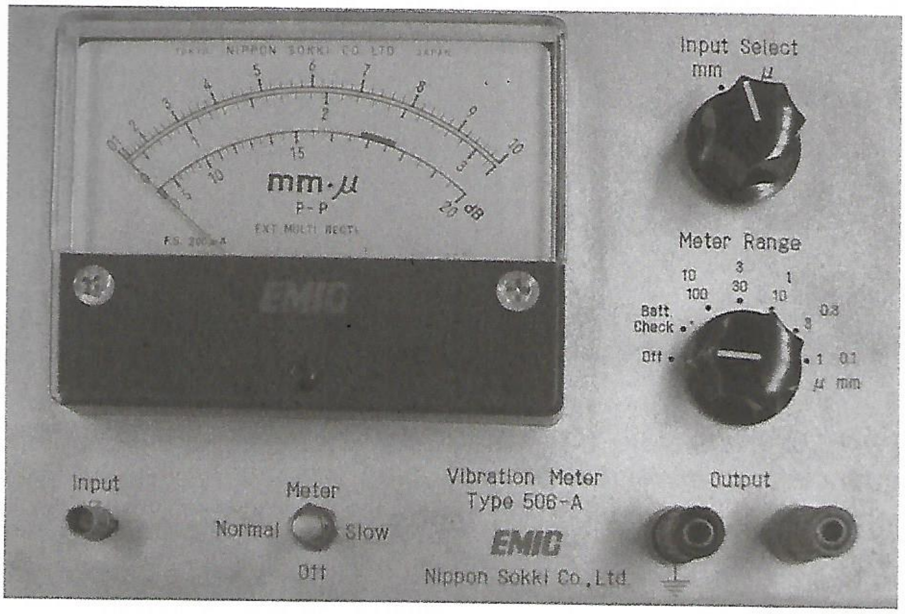


*Displaying a 50Hz vibration*

## DIAGNOSIS continued...

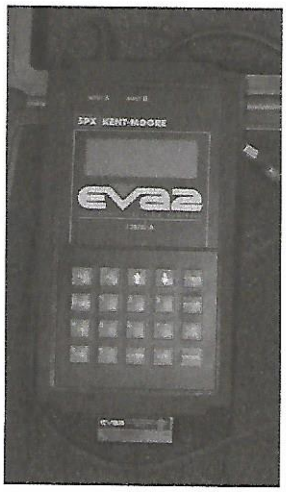
Analogue Vibration Meter

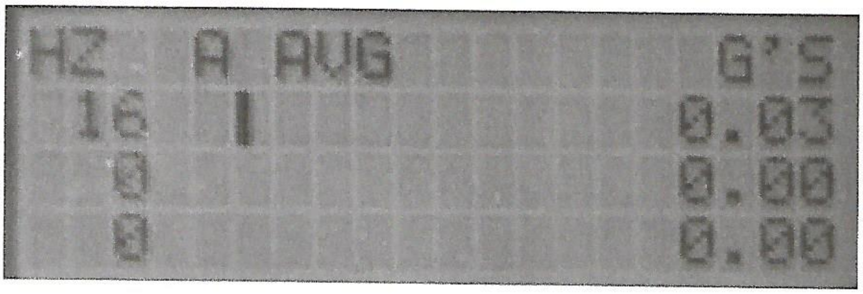
Through the 1980's new car dealerships like Toyota used vibration meters with magnetic pickups like this EMIC unit from AMI Toyota. The sensor transfers the signal to an analogue meter where the scale displays either millimetres (mm), density (μ) or decibels (dB).


TOKYO NIPPON SOKKI CO. LTD. JAPAN
mm·μ
P-P
dB
F.S. 200μA
EXT MULTI RECTL
EMIC
Input Select
mm
μ
Meter Range
10
100
3
30
1
10
0.3
3
0.1
1
μ
mm
Batt. Check
Off
Input
Meter
Normal
Slow
Off
Vibration Meter
Type 506-A
EMIC
Nippon Sokki Co.,Ltd
Output

Electronic Vibration Analysers

During the early 1990's a variety of electronic vibration analysers became available. Of these the most common variety that were required equipment for some dealerships was the EVA and the later EVA2. These tools use a magnetic sensor on a lead and provide vibration information in Hz or RPM, but also include the amplitude in G-forces. An optional add-on feature was a strobe light that could be used for driveshaft balancing.

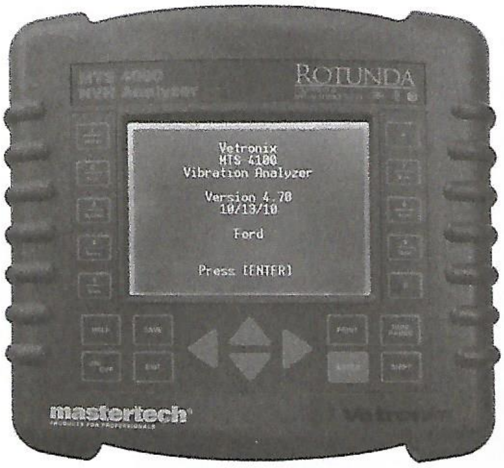

SPX KENT-MOORE
eva2

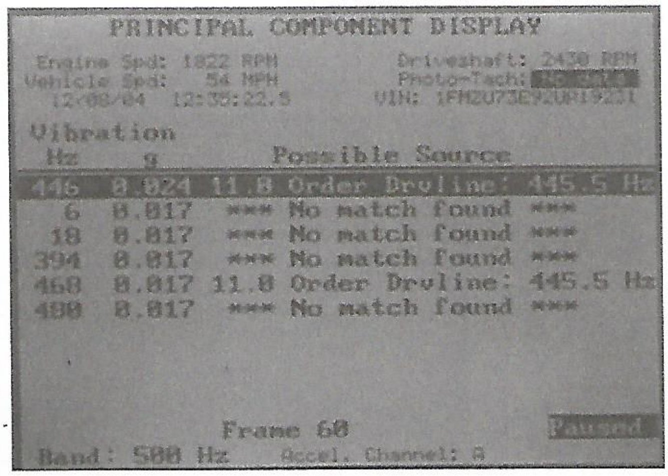


```
HZ  A AVG         G'S
 16  I            0.03
  0               0.00
  0               0.00
```

## DIAGNOSIS continued...

Another electronic vibration analyser was the Mastertech MTS4000 which was absorbed into Bosch in 2010. This unit included all of the functionality of the EVA's with the addition of 16 pin DLC connector to read engine speed and vehicle speed.


MTS 4000
NVH Analyzer
ROTUNDA
Vetronix
MTS 4100
Vibration Analyzer
Version 4.70
10/13/10
Ford
Press [ENTER]
mastertech
PRODUCTS FOR PROFESSIONALS
Vetronix



```
        PRINCIPAL COMPONENT DISPLAY
Engine Spd: 1822 RPM            Driveshaft: 2430 RPM
Vehicle Spd:   54 MPH           Photo-Tach: [illegible]
  12/08/04  12:35:22.5         VIN: 1FM2U73E92UR19231
Vibration
 Hz     g          Possible Source
446  0.024 11.0 Order Drvline: 445.5 Hz
  6  0.017   *** No match found ***
 18  0.017   *** No match found ***
394  0.017   *** No match found ***
460  0.017 11.0 Order Drvline: 445.5 Hz
480  0.017   *** No match found ***

              Frame 60                    Paused
Band: 500 Hz    Accel. Channel: A
```

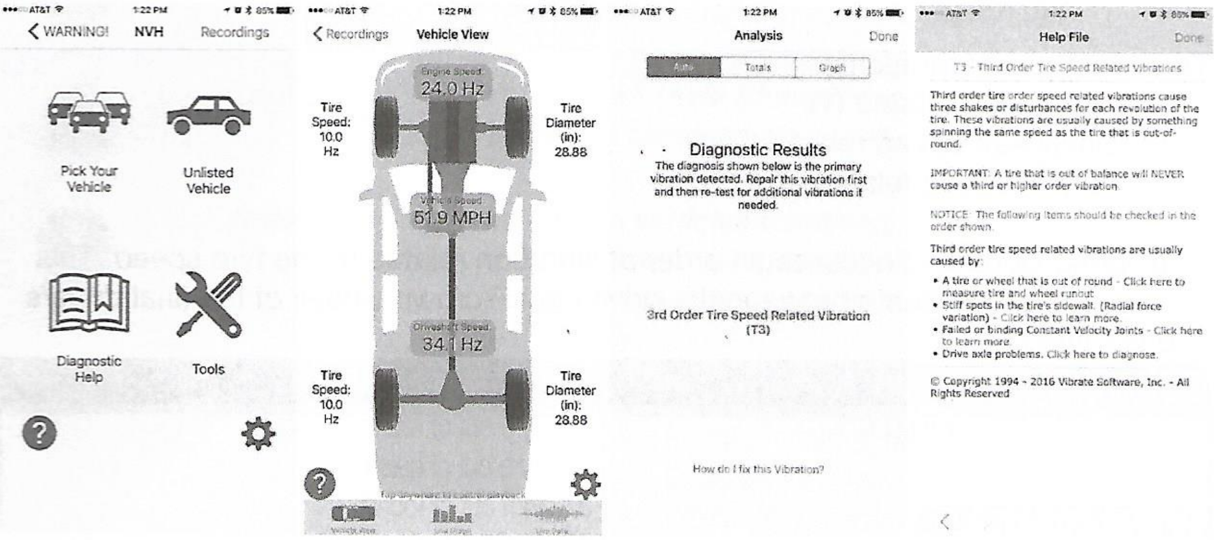
These units were available with some programming that would calculate the order of frequencies. However, the programming was incredibly unreliable. In most situations, the electronic vibration analysers were only suitable for reading frequency, amplitude and order.

A variety of handheld electronic vibration meters are still available but are designed for industrial bearing diagnosis and are not very cost effective for automotive use.

## DIAGNOSIS continued...

### Phone and Tablet Apps

There are a few automotive specific apps for devices that have a built in accelerometer. These apps are in their early stages of development but are showing some signs of future potential.


AT&T
1:22 PM
85%
WARNING!
NVH
Recordings
Pick Your Vehicle
Unlisted Vehicle
Diagnostic Help
Tools
?
Recordings
Vehicle View
Engine Speed:
24.0 Hz
Tire Speed: 10.0 Hz
Tire Diameter (in): 28.88
Vehicle Speed:
51.9 MPH
Driveshaft Speed:
34.1 Hz
Tire Speed: 10.0 Hz
Tire Diameter (in): 28.88
Analysis
Done
Auto
Totals
Graph
Help File
Done

Diagnostic Results

The diagnosis shown below is the primary vibration detected. Repair this vibration first and then re-test for additional vibrations if needed.

3rd Order Tire Speed Related Vibration (T3)

How do I fix this Vibration?

T3 - Third Order Tire Speed Related Vibrations

Third order tire order speed related vibrations cause three shakes or disturbances for each revolution of the tire. These vibrations are usually caused by something spinning the same speed as the tire that is out-of-round.

IMPORTANT: A tire that is out of balance will NEVER cause a third or higher order vibration.

NOTICE: The following items should be checked in the order shown.

Third order tire speed related vibrations are usually caused by:

- A tire or wheel that is out of round - Click here to measure tire and wheel runout
- Stiff spots in the tire's sidewall. (Radial force variation) - Click here to learn more.
- Failed or binding Constant Velocity Joints - Click here to learn more.
- Drive axle problems. Click here to diagnose.

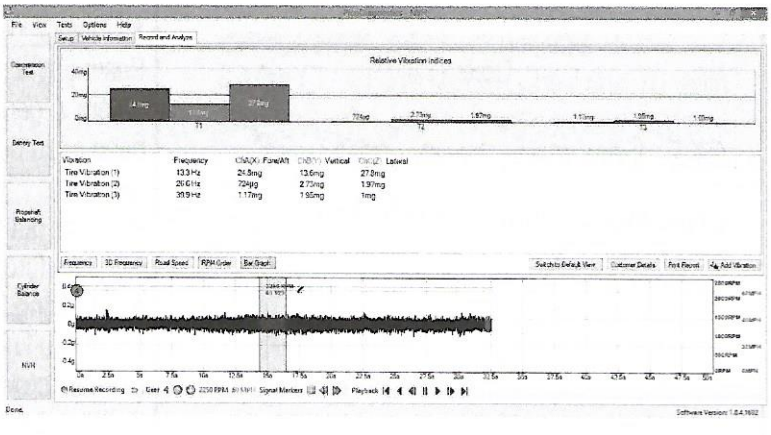
© Copyright 1994 - 2016 Vibrate Software, Inc. - All Rights Reserved

However, there is currently no capability for an external accelerometer that can be mounted to the vehicle. This means that the amplitude of the vibration reaching the devices internal accelerometer are dulled.

### PC Based Vibration Analysis

Arguably the best NVH analyser on the market is currently the Pico Technologies NVH Software coupled to a Picoscope and NVH Kit. The key advantage in this tool is the back end programming. The tool is designed specifically for automotive use and uses the 16 pin DLC connector to read engine speed. The user interface allows for the custom programming of tyre size and final drive ratio, with advanced options for gear ratios, accessory pulley sizes and more.

pico
Technology
NVH Diagnostics Kit
www.picoauto.com
NVH Interface


File
View
Tests
Options
Help
Setup
Vehicle information
Record and Analyze
Compression Test
Battery Test
Propshaft Balancing
Cylinder Balance
NVH
Relative Vibration Indices
40mg
20mg
0mg
T1
T2
T3
Frequency
3D Frequency
Road Speed
RPM Order
Bar Graph
Switch to Default View
Customer Details
Print Report
Add Vibration
0.4g
0.2g
0g
-0.2g
-0.4g
Resume Recording
Playback
Done
Software Version 1.8.4.1602

| Vibration | Frequency | ChA(X) Fore/Aft | ChB(Y) Vertical | ChC(Z) Lateral |
|---|---|---|---|---|
| Tire Vibration (1) | 13.3 Hz | 24.8mg | 13.6mg | 27.8mg |
| Tire Vibration (2) | 26.6 Hz | 724μg | 2.73mg | 1.97mg |
| Tire Vibration (3) | 39.9 Hz | 1.17mg | 1.95mg | 1mg |

## DIAGNOSIS continued...

**Diagnosing the cause of vibrations**
When a vehicle has a vibration it will have a certain frequency (Hz) that will be most evident at a specific speed. By calculating the tyre diameter, differential ratio, gear ratio, engine speed and number of cylinders it is possible to identify the source of the vibration/s.

Three groups of vibrations:

- Tyre speed related (T)
- Driveshaft speed related (D)
- Engine speed related (E)

Tyre speed vibrations occur at an order of vibration related to the tyre speed. This includes all components between the driven gear (crown wheel) of the final drive/s and the tyres.

| Order | Tips |
|---|---|
| First (T1) | 1. Tyre out of round<br>2. Tyre out of balance<br>3. Rim out of round<br>4. Radial force variation<br>5. Brake runout<br>6. Hub runout<br>7. Wheel stud circle runout<br>8. Axle issues |
| Second (T2) | 1. Tyre out of round<br>2. Tyre force variation<br>3. Axle issues |
| Third (T3) | 1. Tyre out of round<br>2. Tyre force variation<br>3. Faulty inner CV Joint (tripod type) |
| Sixth (T6) | • Tyre out of round<br>• Tyre force variation<br>• Faulty inner or outer CV Joint (double offset type) |
| Other (Tx)<br>SKF Bearings have Info on vibration crownwheel bearings will make. | Bearing and gear failures may produce other vibration orders. A general rule is that if the tyre and wheel have been ruled out, the Tx issue will be bearing or gear related<br>• Tyre out of round<br>• Tyre force variation<br>• Bearing failure<br>• If you know how many teeth are on the differentials crown wheel it will be possible to calculate the vibration orders a fault will generate: 4.100:1 = 41 tooth crown wheel and 10 tooth pinion, a crown wheel fault will generate a T41 vibration. |

## DIAGNOSIS continued...

Driveshaft speed vibrations occur at an order of vibration related to the driveshaft speed. This includes all components between the output shaft of the transmission and the pinion gear of the final drive/s.

*Note:* *The Driveshaft refers to the shaft connecting the Transmission/Transfer to the Differential!*

*Caution:* *A CV Shaft (Axle Shaft) turns at wheel speed and therefore creates tyre speed related vibrations!*

*Note:* *When the vehicles transmission and transfer case (if fitted) are in 1:1 gear ratio/s, the Driveshaft and Engine speeds are synchronised!*

| Order | Tips |
|---|---|
| First (D1) | • Excessive driveshaft runout<br>• Driveshaft out of balance<br>• Differential input shaft runout<br>• Transmission output shaft runout |
| Second (D2) | • Faulty Universal Joint/s<br>• Faulty Engine/Transmission mount/s<br>• Driveshaft phasing error<br>• Twisted driveshaft<br>• Excessive driveshaft angles (U-Joint type) |
| Third (D3) | • Faulty CV Joint/s (tripod type)<br>• Excessive driveshaft angles (CV Joint type) |
| Sixth (D6) | • Faulty CV Joint (double offset type)<br>• Faulty Flex Joint |
| Other (Dx) | • Bearing failure<br>• If you know how many teeth are on the differentials pinion gear it will be possible to calculate the vibration orders a fault will generate: 4.100:1 = 41 tooth crown wheel and 10 tooth pinion, a pinion gear fault will generate a D10 vibration. |

## DIAGNOSIS continued...

Engine speed vibrations occur at an order of vibration related to the engine RPM. This includes all internal engine components as well as all components being driven off the crankshaft (this includes the harmonic balancer and the driveplate/flywheel).

| Order | Tips |
|---|---|
| Half (E0.5) | • Single cylinder misfire<br>• Camshaft/Phaser out of balance |
| First (E1) | • Faulty engine, transmission or exhaust mounts<br>• Tight/stiff cables or hoses transferring normal vibrations to the body<br>• Harmonic Balancer out of balance<br>• Flywheel/Clutch out of balance<br>• Driveplate/Torque Converter out of balance<br>• Crankshaft out of balance |
| One and One Half (E1.5) | • Normal combustion vibration from 3 cylinder engine<br>• Faulty engine, transmission or exhaust mounts<br>• Tight/stiff cables or hoses transferring normal vibrations to the body |
| Second (E2) | • Normal combustion vibration from 4 cylinder engine<br>• Faulty engine, transmission or exhaust mounts<br>• Tight/stiff cables or hoses transferring normal vibrations to the body<br>• Balance shaft timing error |
| Two and One Half (E2.5) | • Normal combustion vibration from 5 cylinder engine<br>• Faulty engine, transmission or exhaust mounts<br>• Tight/stiff cables or hoses transferring normal vibrations to the body |
| Third (E3) | • Normal combustion vibration from 6 cylinder engine<br>• Faulty engine, transmission or exhaust mounts<br>• Tight/stiff cables or hoses transferring normal vibrations to the body |
| Fourth (E4) | • Normal combustion vibration from 8 cylinder engine<br>• Faulty engine, transmission or exhaust mounts<br>• Tight/stiff cables or hoses transferring normal vibrations to the body |
| Other (Ex) | • Belt driven accessories<br>• Gear driven accessories |

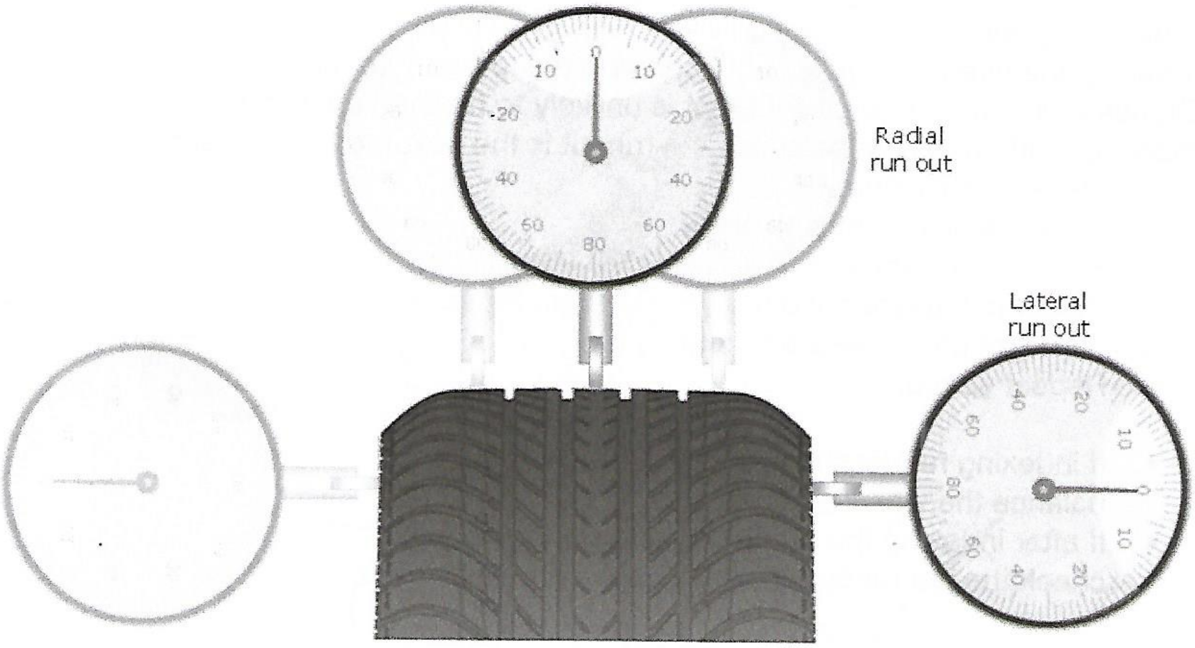
# TYRE SPEED VIBRATIONS

**Tyre runout**

Most technicians are unaware that excessive tyre runout or Radial Force Vibration (RFV) is a greater cause of vibrations in vehicles than tyre imbalance. If a car presents with a vibration complaint, before removing the wheels for balancing, they should be checked for excessive runout with a dial indicator.

Procedure:

1. Raise vehicle
2. Mount a suitable dial indicator
3. Measure tyre radial runout in three places (inside, outside and centre of tread)
4. Measure tyre lateral runout on the inside and outside of the tyre



- If less than 1.5mm, remove, balance and refit wheel
- If greater than 1.5mm but less than 3.0mm index the tyre
- If greater than 3.0mm check the runout on the rim

*Caution:* *All runout values provided are generic, always refer to manufacturers specifications where available!*

## TYRE SPEED VIBRATIONS continued...

### Fitting New Tyres

When fitting tyres the following procedure provides best practice:

1. Measure the lowest point on the rim and mark its location
2. Align this mark with the RED DOT of the new tyre (highest RFV point
3. If there is no low point on the rim align the YELLOW DOT (lightest point in the tyre) with the valve stem
4. Balance the tyre

*Note:* The order of precedence is because the balance will compensate for the yellow dot but the balance cannot compensate for excessive RFV!

### Indexing tyres

Indexing the tyres is a method of achieving the lowest tyre runout.
On used tyres the factory RFV point is unlikely to be lined up with the original marking. Without a RFV balancer, the runout is the next most important factor.

1. Measure tyre runout
2. Mark the high spot with chalk
3. Remove the wheel
4. Dislodge the tyre bead from the rim and rotate 90°
5. Refit tyre and measure runout
6. Repeat as required

- If indexing reduces the runout to less than 1.5mm, balance the wheel and refit
- If after indexing the runout is greater than 1.5mm, check the rim runout and replace the rim and/or tyre

### Balancing

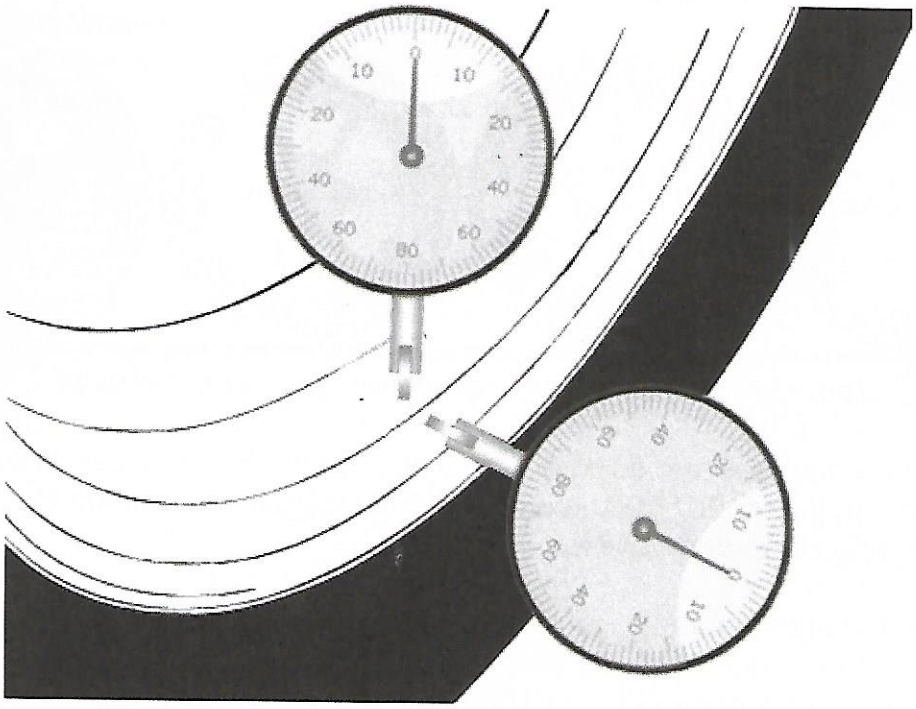
Wheel balancers measure and locate the imbalance of a wheel. When a vehicle presents with a vibration, balance is usually checked first. However, it is possible to balance an out of round tyre so always check tyre runout first.

- If the wheel requires more the 150g of weight to balance, check the rim runout and replace the rim and/or tyre

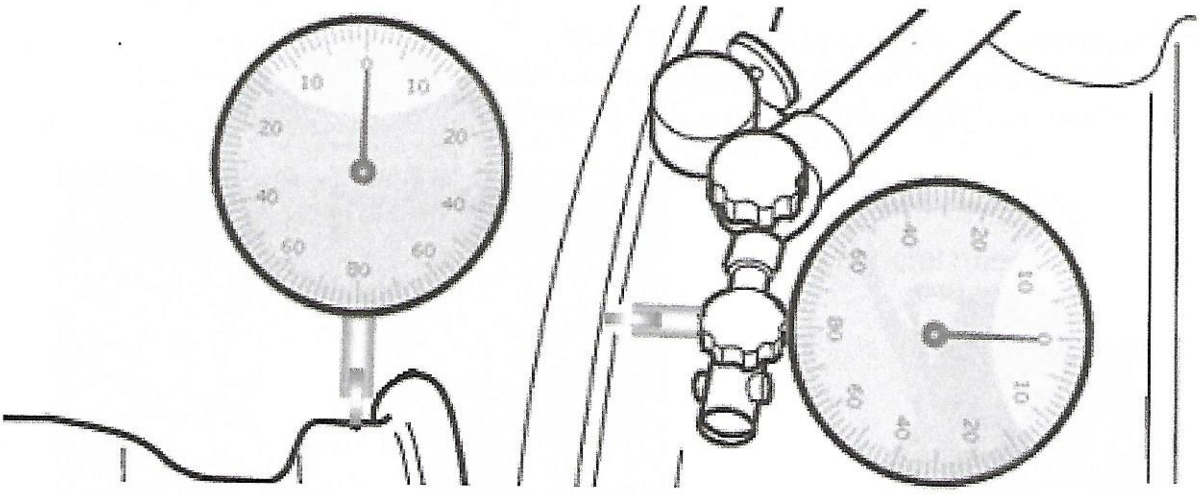
## TYRE SPEED VIBRATIONS continued...

**Rim runout**

Rim runout can be checked with or without the tyre mounted
Position the dial indicator to measure the runout at the tyre bead location
Measure the radial and lateral runout



*Rim runout measured on the outside of the bead location*



*If the tyre has been removed the radial (left) and lateral (right) runout is measured on the inside of the rim where the tyre bead locates.*

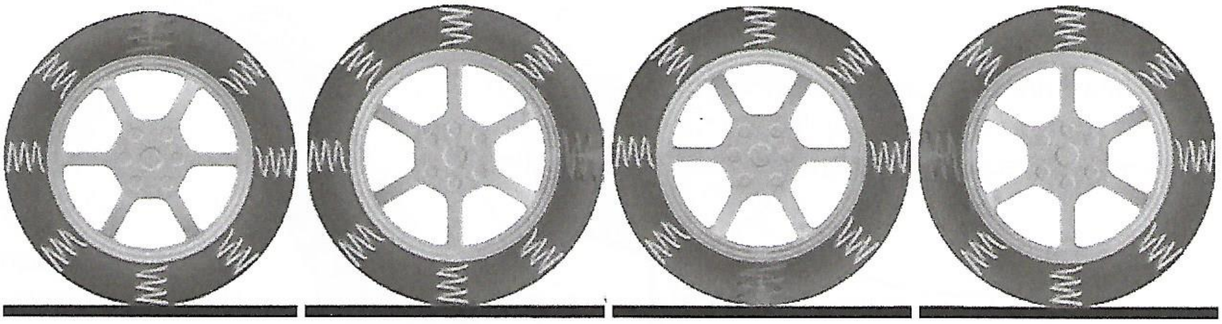
- Runout must be less than 0.7mm for alloy rims
- Runout must be less than 1.1mm for steel rims

*Caution:* *Runout will increase by up to 50% at the outside diameter of the tyre, index the tyre to counteract any rim runout!*

## TYRE SPEED VIBRATIONS continued...

### Radial Force Variation

Radial Force Variation (RFV) refers to a variation in the stiffness of the strengthening ply's in the sidewalls of the tyre. RFV can present a dilemma that often sends technicians off course, a tyre with an RFV issue will have acceptable runout and will be in balance, yet it will still cause a vibration when driven on the road.



*Radial Force Variation usually presents as a first order tyre vibration.*

As vehicle ride quality is refined with each new model, RFV diagnosis is becoming more important. In July 2017 GM made RFV Balancers a requirement for all countries selling US export vehicles.

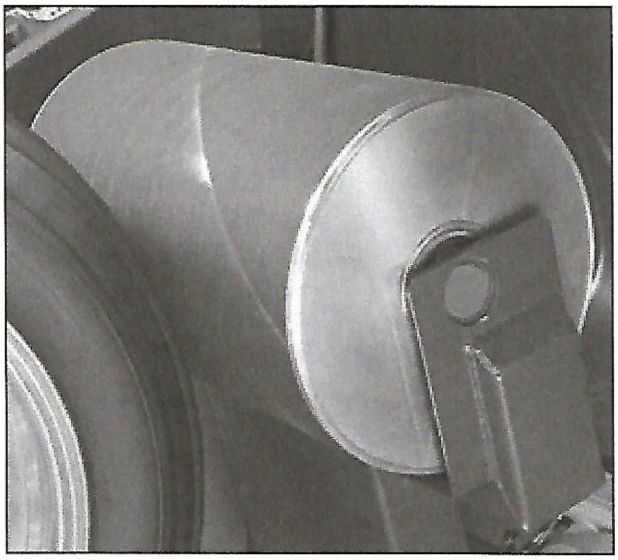
Tyre manufacturers mark the tyres greatest RFV on the sidewall with a red dot. This red dot should be aligned with the lowest point of radial runout on the rim. The RFV mark on a new tyre is of more importance than the yellow dot which indicates the lightest point which can be compensated by balancing.

This issue can be diagnosed in two methods:

- Substitute a known good set of wheels and tyres
- Have the tyres balanced on a RFV Balancer

HUNTER
Road Force Touch

*Hunter RFV Balancer*



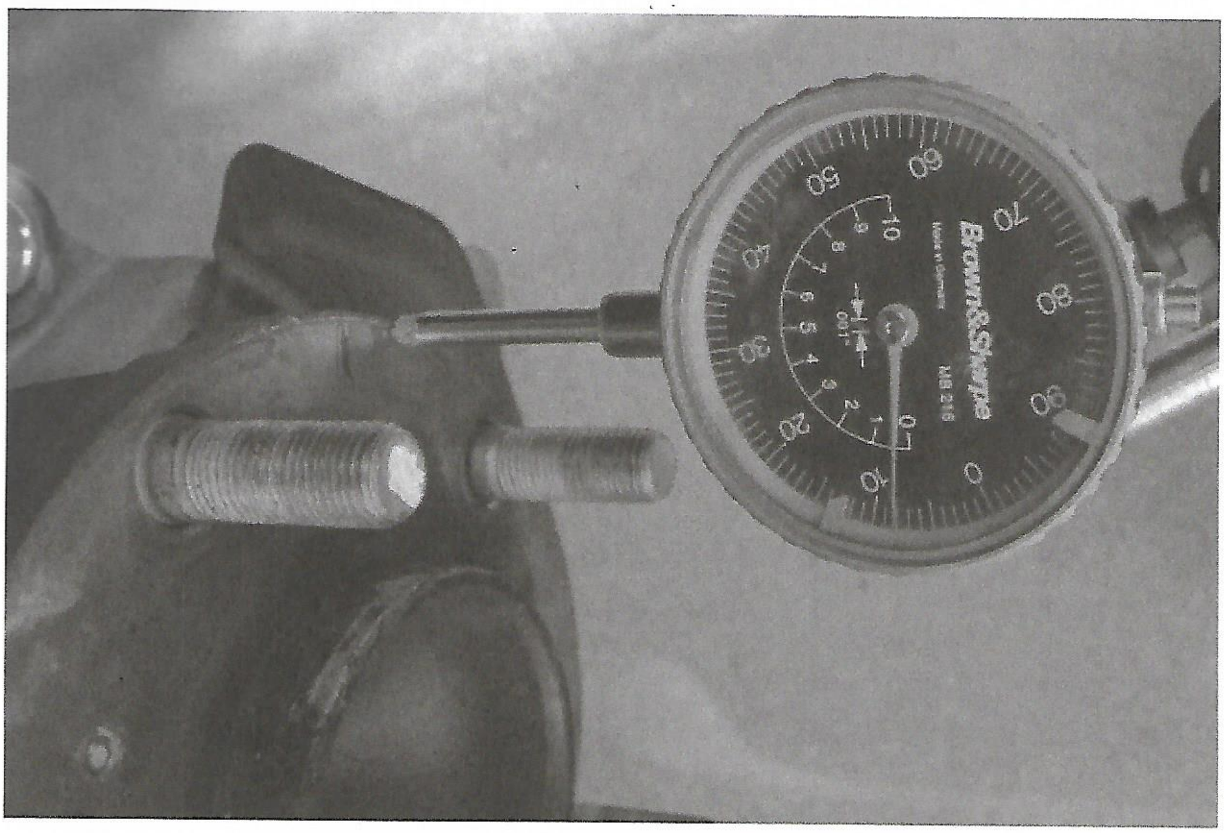
*Hunter RFV Load Roller*

## TYRE SPEED VIBRATIONS continued...

### Hub Runout

If the cause of a tyre speed related vibration cannot be identified in the tyres and/or wheels, further measurements will be required to diagnose the fault.

Hub runout is the next most common factor, mainly due to the amplification of the irregularity when projected from the hub to the outside diameter of the tyre. Depending on the hub diameter and tyre size lateral runout at the hub can be increased up to 5x where the tyre contacts the road.

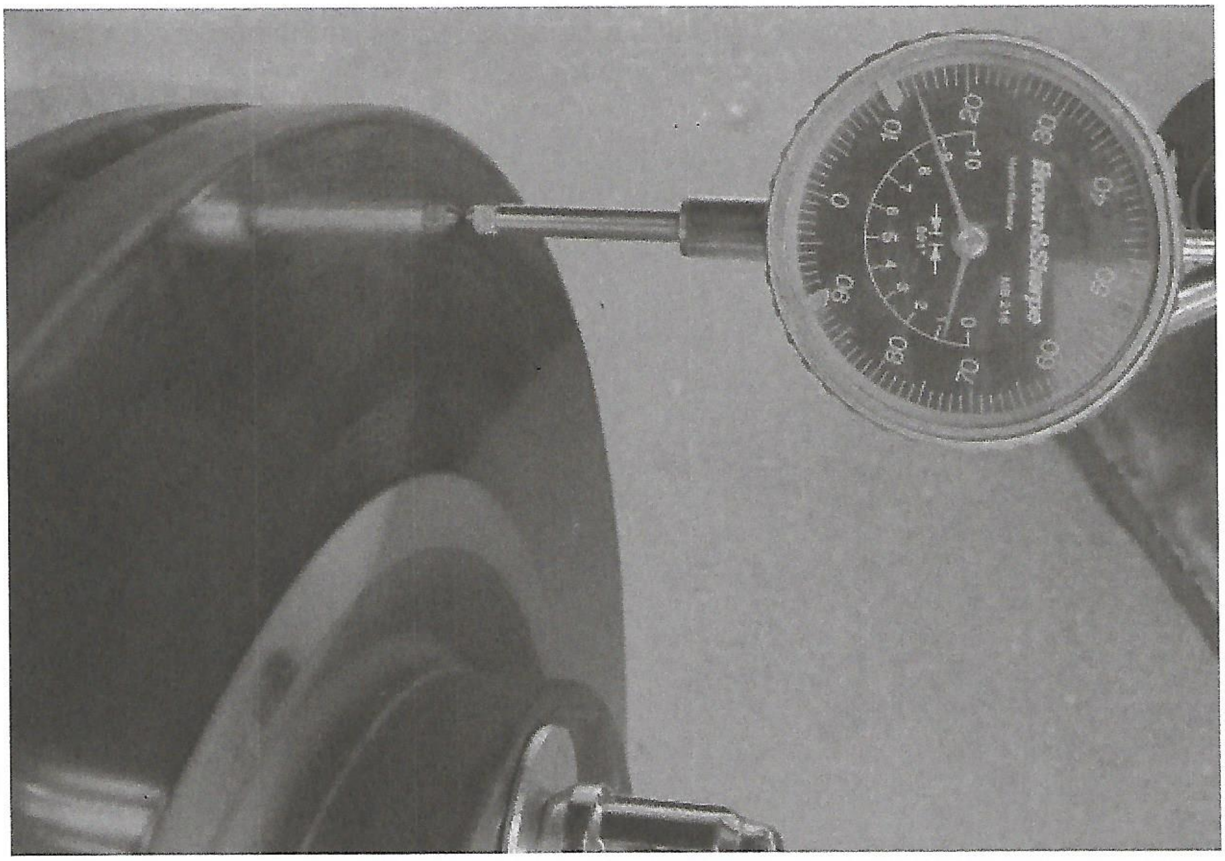


- Hub runout values vary across manufacturers, as a general rule it should be less than 0.03mm (30µm)

# TYRE SPEED VIBRATIONS continued...

## Brake Runout

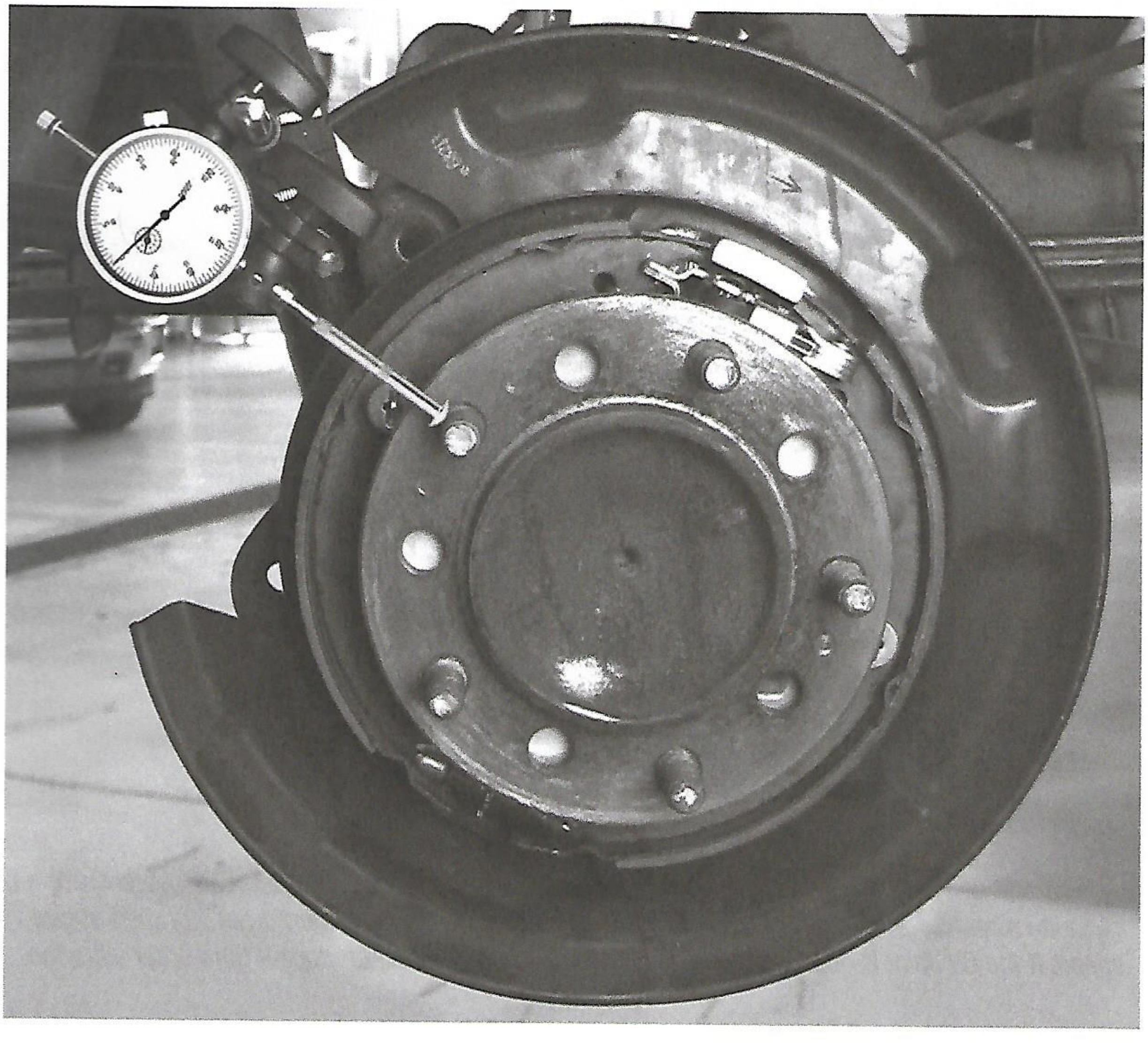
Typically brake runout issues present as a brake shudder rather than a driving vibration. However, if it was the cause of such a vibration the amplitude would usually increase dramatically when the brake pedal is depressed, especially on the case of higher wheel speeds.



- Disc runout should not exceed 0.07mm (70μm)

## TYRE SPEED VIBRATIONS continued...

**Wheel Stud Circle Runout**
The Wheel Stud circle runout should not vary. If out it is caused by a manufacturing defect. Therefore it is usually found on new vehicles or on replacement parts. One other factor that can exacerbate Wheel Stud circle runout is the fitment of aftermarket wheels. All factory rims are hub centred which means the hub spigot locates the rim laterally. Some aftermarket rims are stud centred, the fitment of these rims may cause a vibration.



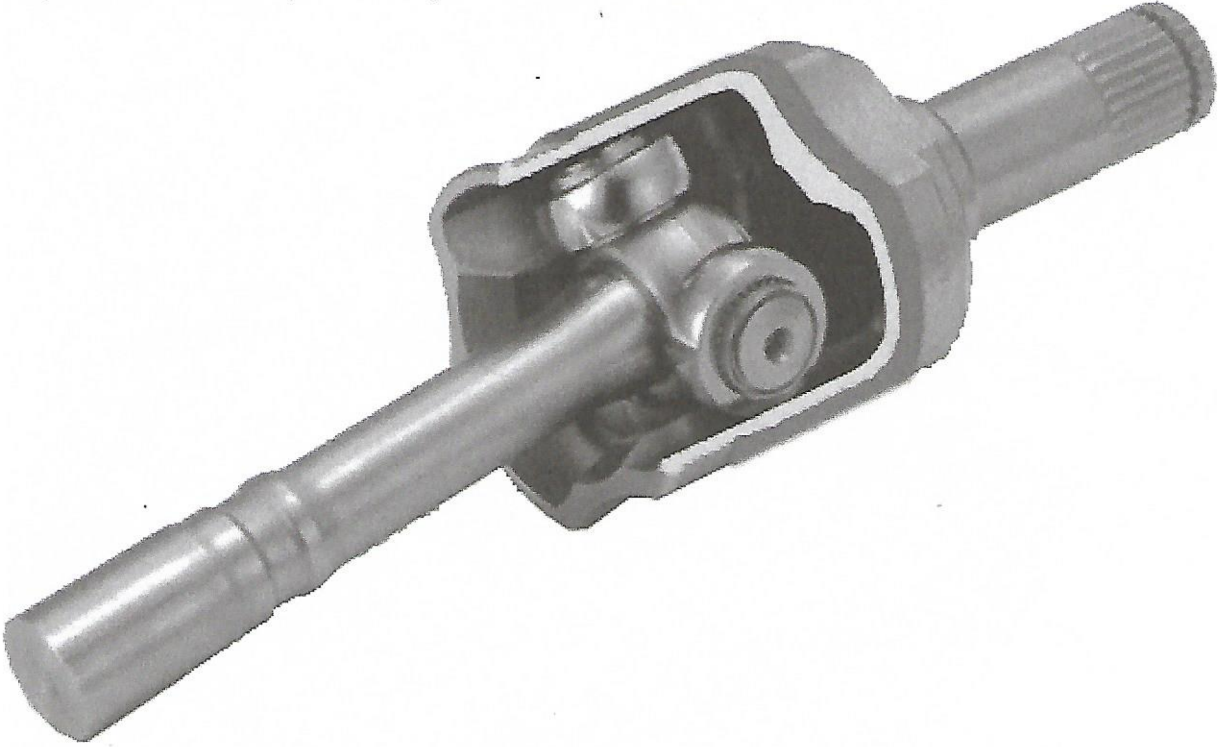
- Measure the variation between ALL studs, total variation should not exceed 0.25mm.

## TYRE SPEED VIBRATIONS continued...

**Constant Velocity (CV) Joint - Tripod type**
A tripod type CV Joint usually has a limited operating angle and is used as the inner axleshaft joint because it allows the inner joint to slide within the housing to shorten and lengthen the shaft with suspension movement. These joints are also called Plunging Tripod Joints (PTJ's).

The maximum operating angle is 26°-30°. However, at angles greater than 15°-17° it will produce a third order vibration that increases with amplitude as the angle increases.

If the vehicle is producing a T3 vibration, check the operating angles with an inclinometer. If the operating angle is within specification dismantle the joint and inspect for wear. Replace the joint if wear is found.



*A faulty tripod CV Joint (usually used as an inner joint) will produce a third order vibration at tyre speed. If the CV Joint is operating at an excessive angle it will also produce a third order vibration.*

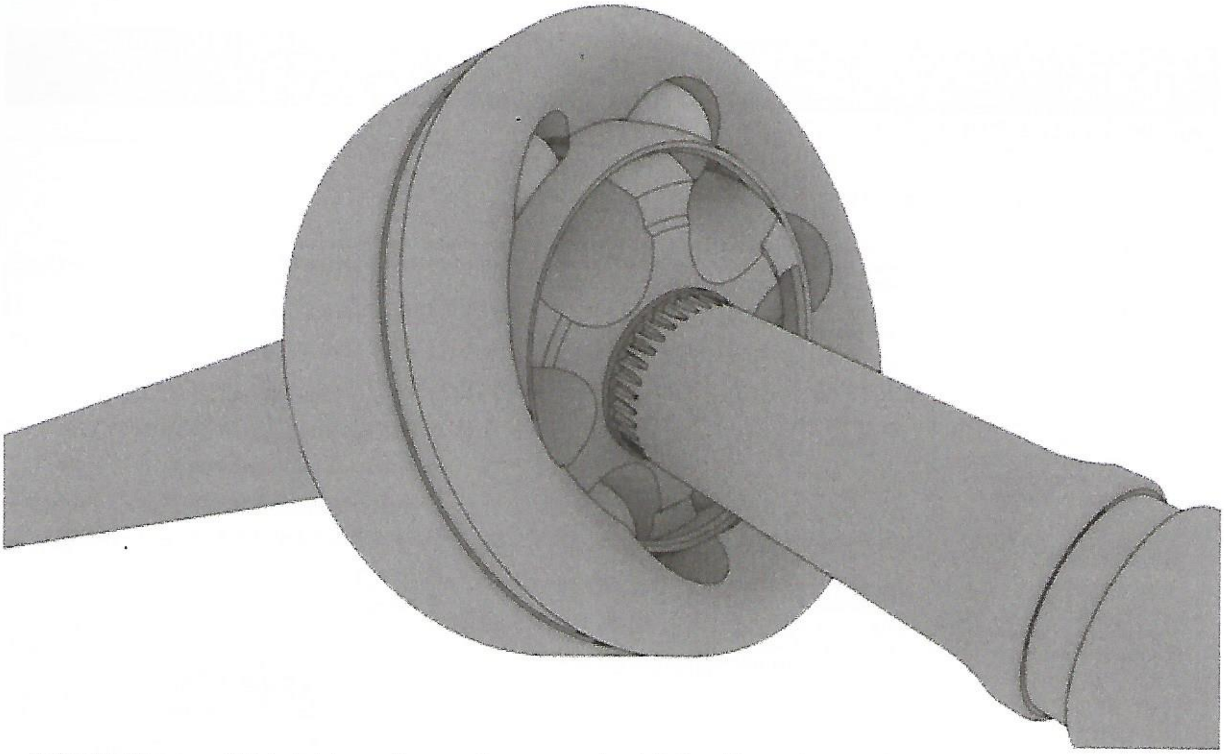
## TYRE SPEED VIBRATIONS continued...

### Constant Velocity (CV) Joint - Rzeppa type

A Rzeppa type CV Joint has a much greater operating angle and can be used as either an inner or outer axleshaft joint.

The maximum operating angle is 40°. However, at angles greater than 20° it will produce a sixth order vibration that increases with amplitude as the angle increases.

If the vehicle is producing a T6 vibration, check the operating angles with an inclinometer. If the operating angle is within specification dismantle the joint and inspect for wear. Replace the joint if wear is found.



*A faulty Rzeppa CV Joint (usually used as an outer joint) will produce a sixth order vibration at tyre speed. If the CV Joint is operating at an excessive angle it will also produce a sixth order vibration.*

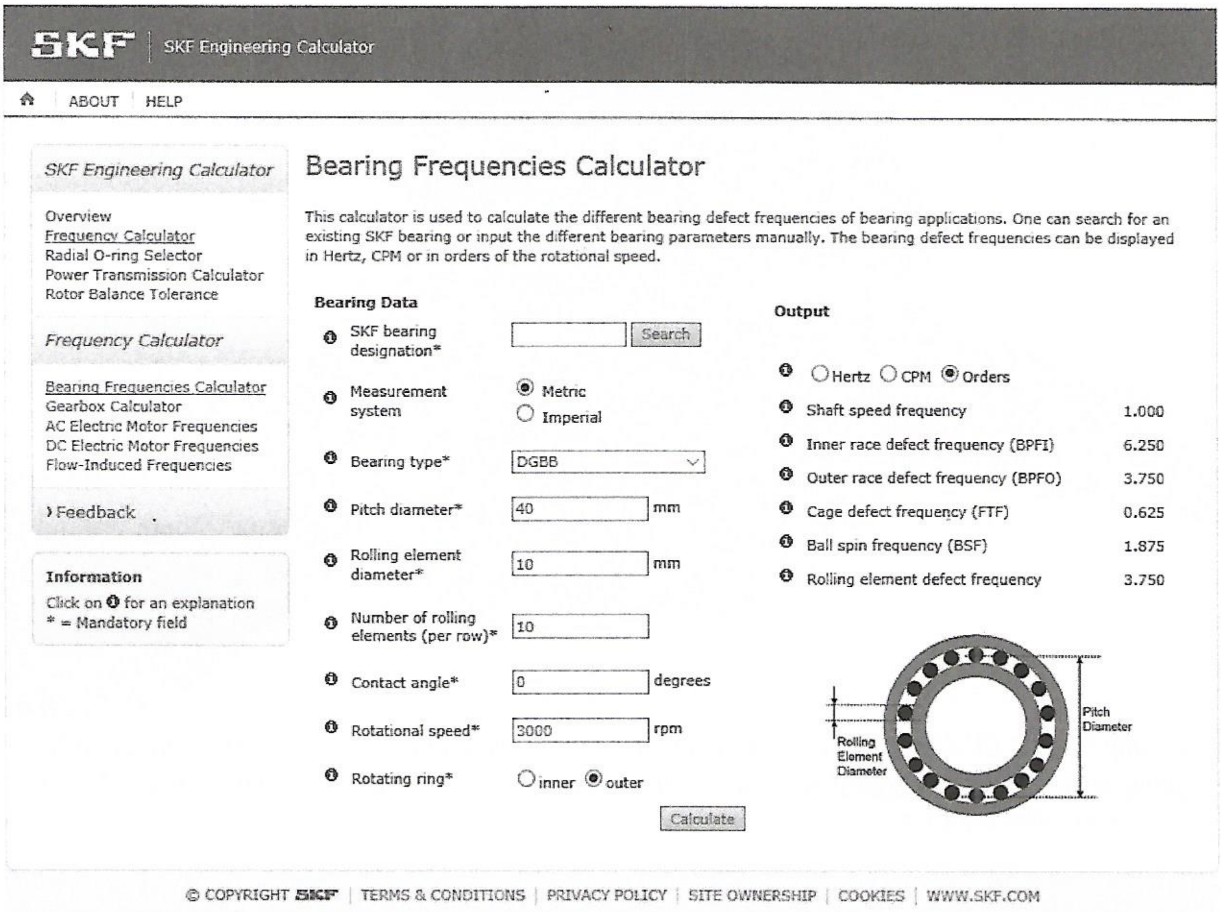
## TYRE SPEED VIBRATIONS continued...

**Bearing failure vibrations**

There are a variety of vibrations that can be generated by a failing bearing, the most common examples are:

- Race failure
- Rolling element failure
- Cage failure

Calculating the vibration order of the different elements is difficult. However, if you know the bearing specifications it is possible with the help of an online calculator such as the one found on the website for bearing manufacturer SKF.
Search; http://webtools3.skf.com/engcalc/CalcBearingFrequencies.do and create a free account to access the calculator.


SKF
SKF Engineering Calculator
ABOUT
HELP
SKF Engineering Calculator
Overview
Frequency Calculator
Radial O-ring Selector
Power Transmission Calculator
Rotor Balance Tolerance
Frequency Calculator
Bearing Frequencies Calculator
Gearbox Calculator
AC Electric Motor Frequencies
DC Electric Motor Frequencies
Flow-Induced Frequencies
› Feedback
Search
Calculate
Pitch Diameter
Rolling Element Diameter
© COPYRIGHT SKF | TERMS & CONDITIONS | PRIVACY POLICY | SITE OWNERSHIP | COOKIES | WWW.SKF.COM

Bearing Frequencies Calculator

This calculator is used to calculate the different bearing defect frequencies of bearing applications. One can search for an existing SKF bearing or input the different bearing parameters manually. The bearing defect frequencies can be displayed in Hertz, CPM or in orders of the rotational speed.

Information
Click on ❶ for an explanation
* = Mandatory field

**Bearing Data**

SKF bearing designation*: 
Measurement system: ● Metric ○ Imperial
Bearing type*: DGBB
Pitch diameter*: 40 mm
Rolling element diameter*: 10 mm
Number of rolling elements (per row)*: 10
Contact angle*: 0 degrees
Rotational speed*: 3000 rpm
Rotating ring*: ○ inner ● outer

**Output**

○ Hertz ○ CPM ● Orders

| | |
|---|---|
| Shaft speed frequency | 1.000 |
| Inner race defect frequency (BPFI) | 6.250 |
| Outer race defect frequency (BPFO) | 3.750 |
| Cage defect frequency (FTF) | 0.625 |
| Ball spin frequency (BSF) | 1.875 |
| Rolling element defect frequency | 3.750 |

*By entering the Bearing Data on the left list, the vibration orders are provided on the right.*

Note: *When analysing the order of vibration the RPM is irrelevant as it has no effect on order!*

# TYRE & DRIVESHAFT SPEED VIBRATIONS

**Final Drive vibrations**

There are two distinct vibrations that can be produced by the final drive, they can occur individually or simultaneously:

- As the pinion rotates at driveshaft speed it will create a driveshaft speed related vibration
- As the crown wheel rotates at tyre speed it will create a tyre speed related vibration while driving in a straight line.

*Note:* *Vibrations created by the differential gear and/or limited slip unit are very difficult to calculate as they are based on the differential speed between each of the driven wheels.*

*These vibrations can usually be identified when they occur only when the wheels are travelling at different speeds (eg. cornering) and absent while driving in a straight line!*

**Crown Wheel vibrations**

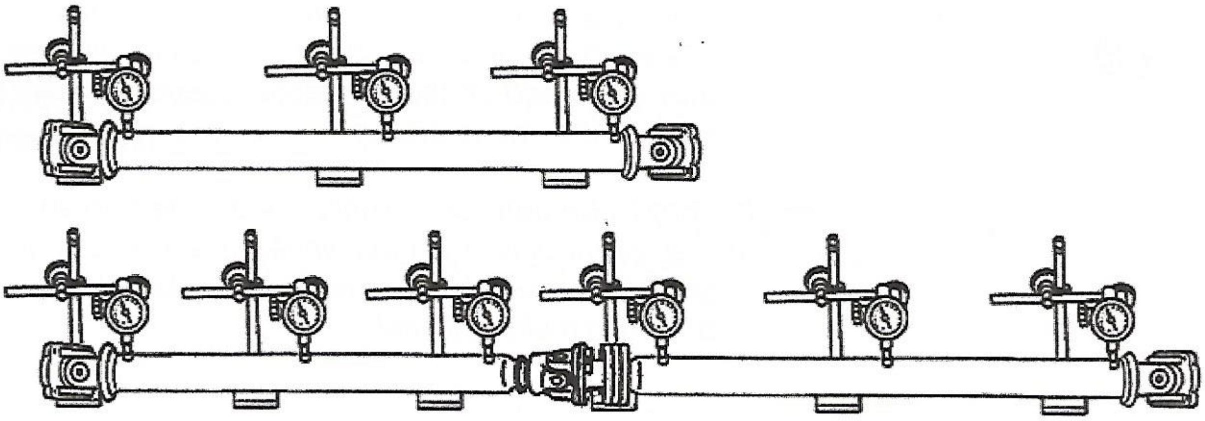
If a defect exists in the Crown Wheel it will produce a tyre speed related vibration. The order of vibration for the Crown Wheel is the factor of the number of teeth on the crown wheel (eg. 4.100:1 that has a 41 tooth crown wheel and 10 tooth pinion), a crown wheel fault will generate a T41 vibration.

**Pinion Gear vibrations**

If a defect exists on the Pinion Gear it will produce a driveshaft speed related vibration. The order of vibration for the Pinion Gear is the factor of the number of teeth on the pinion gear (eg. 4.100:1 that has a 41 tooth crown wheel and 10 tooth pinion), a pinion gear fault will generate a D10 vibration.

# DRIVESHAFT SPEED VIBRATIONS

**Driveshaft Runout**
Excessive driveshaft runout is the most likely cause of a D1 vibration. It is critical that runout is checked and corrected (if necessary) before the driveshaft is balanced. As with tyres, it is possible to balance a driveshaft that has excessive runout. Runout should be inspected with a dial indicator at 3 positions (each end and the centre) and if it is a two piece shaft this must be done for each section (6 measurements)



Driveshaft runout varies a lot between manufacturers:
Typical maximum runout limits are typically between 0.70mm and 1.30mm.

- If runout is less than 0.70mm runout should not cause a vibration
- If runout is between 0.70 and 1.30mm, check manufacturers specifications
- If runout exceeds 1.30mm check the Differential Pinion runout and the Transmission/Transfer output runout.

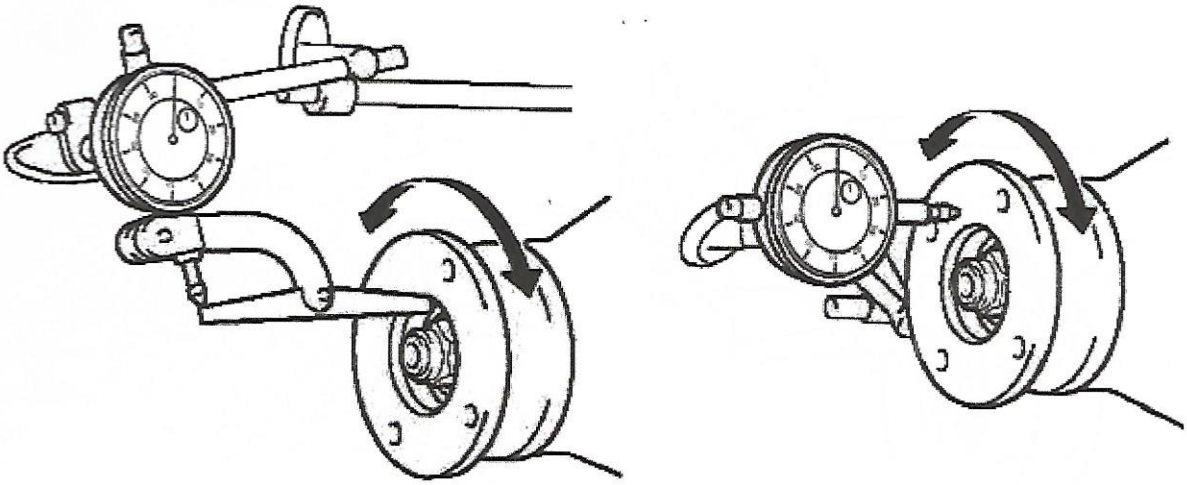
*Note:* *Try indexing the Driveshaft and pinion, mark the original position and recheck at 90° and/or 180° intervals!*

## DRIVESHAFT SPEED VIBRATIONS continued...

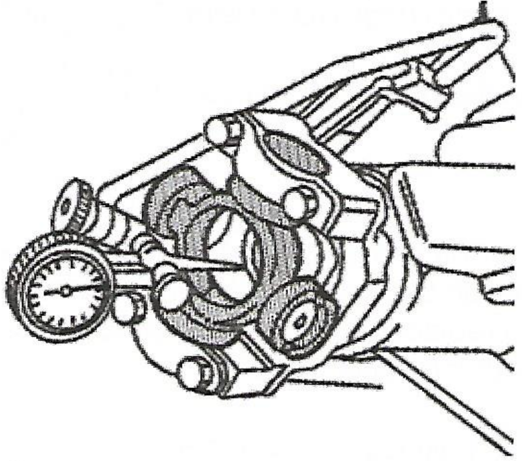
### Differential Pinion runout

Note: *Checking the differential pinion runout should only be necessary if excessive runout is measured at the driveshaft end adjacent to the pinion!*

Remove the driveshaft and measure the runout as indicated in the images below:



*Differential Pinion Flange lateral runout (left) and axial runout (right)*



*Differential Pinion lateral runout, Non-flanged Type using Special Service Tool*

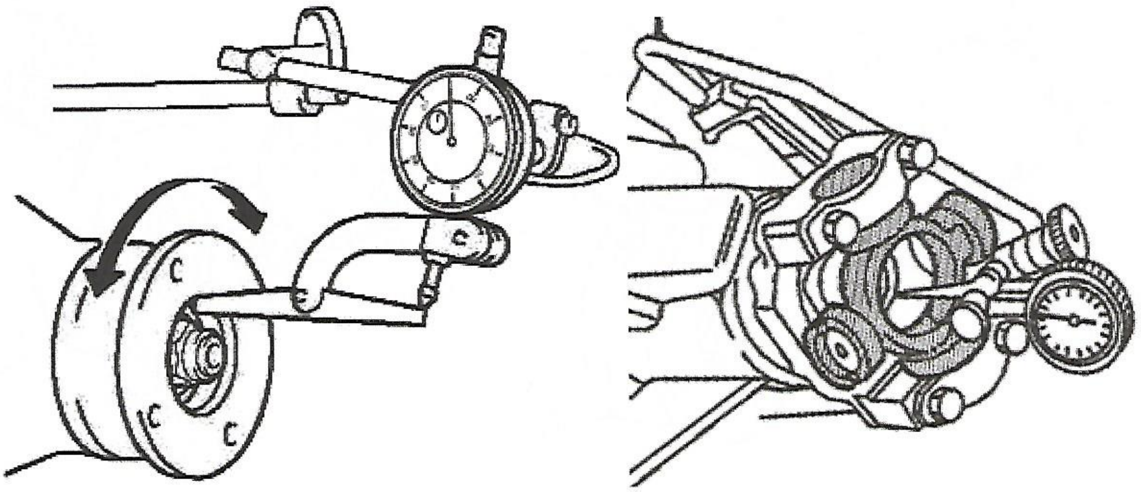
- Pinion runout (lateral or axial) should not exceed 0.20mm

## DRIVESHAFT SPEED VIBRATIONS continued...

### Transmission/Transfer output runout

*Note:* *Checking the transmission/transfer output runout should only be necessary if excessive runout is measured at the driveshaft end adjacent to the output!*

Remove the driveshaft and measure the runout as indicated in the images below:



*Transmission/Transfer Output lateral runout, Flange Type (left) and Non-flanged Type (right)*

- Transmission/Transfer output runout (lateral or vertical) should not exceed 0.20mm

**Driveshaft Indexing**
Indexing involves refitting the driveshaft connecting flanges to alternative positions to offset the runout between the two mating surfaces and achieve the lowest runout without having to replace any components. Often a driveshaft speed related vibration can be fixed with indexing.

As a vehicle ages and multiple repairs have been carried out the chances of the driveshaft being incorrectly indexed increases.

1. Mark the starting point on both sides of the connection
2. Check the runout and note it down
3. Repeat for all possible combinations

- If the lowest runout is within specification align it the point of lowest runout
- If excessive runout cannot be counteracted with indexing check the Transmission/Transfer Output Runout and the Differential Pinion Runout.

## DRIVESHAFT SPEED VIBRATIONS continued...

### Universal Joints

A faulty universal joint will most commonly produce a second order (D2) vibration.
Check the universal joint for rust marks indicating roller failure
Check for freeplay by twisting the two halves in opposite directions, if any play is evident replace the joints
A tight universal joint can also be the cause of a D2 vibration. to check for tight joints remove the shaft and check that the joint moves freely in all directions.

*Note:* *If new joints are fitted, it is possible that:*

- *They may have been incorrectly fitted*
- *Incorrectly indexed while fitting*
- *Damaged during fitment*

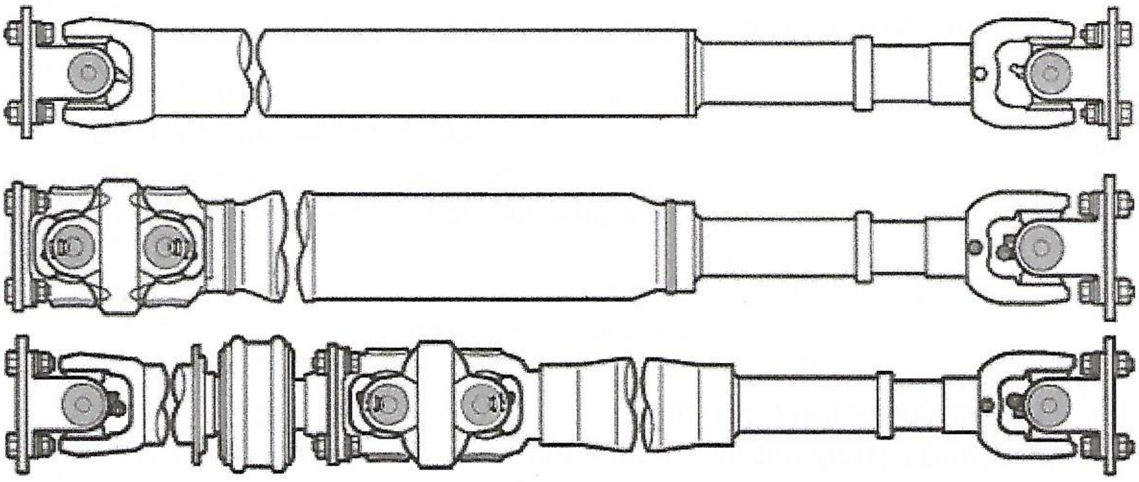
*Don't assume that new joints means they are not the cause of a vibration!*

### Engine and Transmission Mountings

Faulty engine and or transmission mountings can cause the operating angles of the driveshaft to be excessive causing a D2 vibration.
See the Driveshaft Angle topic and also the Engine and Transmission Mounting topic in the engine speed related section for further information.

## DRIVESHAFT SPEED VIBRATIONS continued...

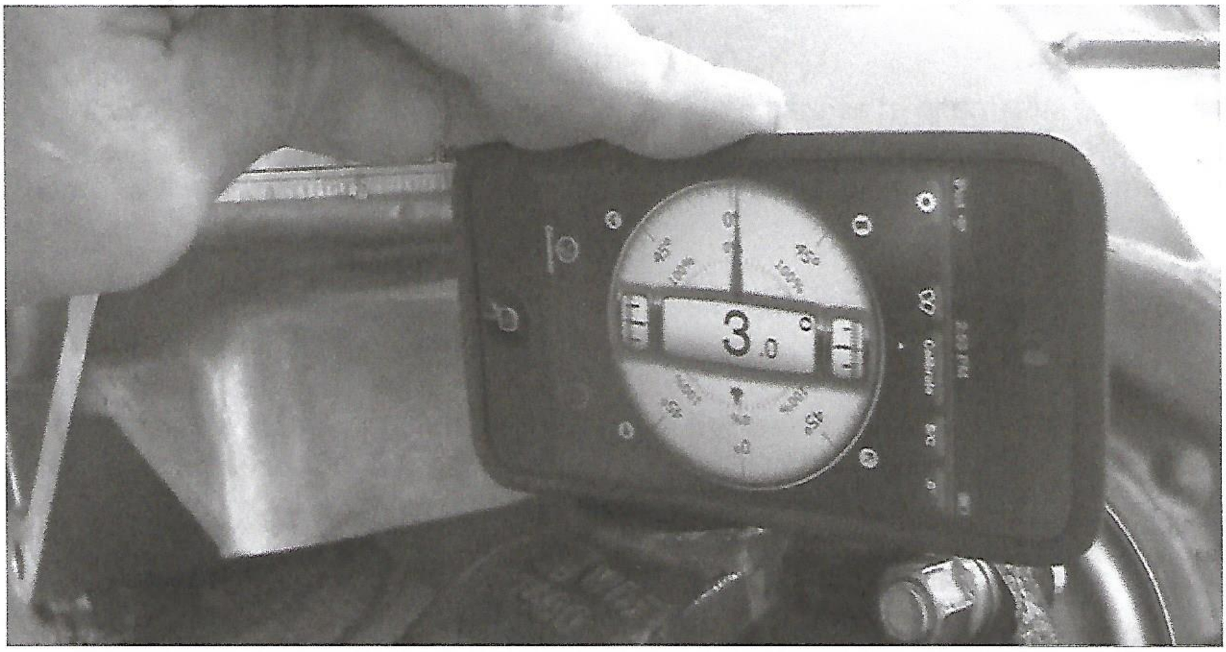
**Driveshaft Phasing (U-Joint shafts)**
Incorrect phasing can occur when a Driveshaft has an integrated slip joint. If a driveshaft is incorrectly phased it will cause it to bind twice per revolution producing a D2 vibration. The greater the phasing error (to a maximum of 90°) the greater the amplitude of the vibration.



*The joints should be aligned regardless of how many joints are in the shaft*

1. Using a protractor or an inclinometer set the front universal joint exactly horizontal
2. Measure all of the other universal joints in the shaft

- They should be no more than 3° out of phase.

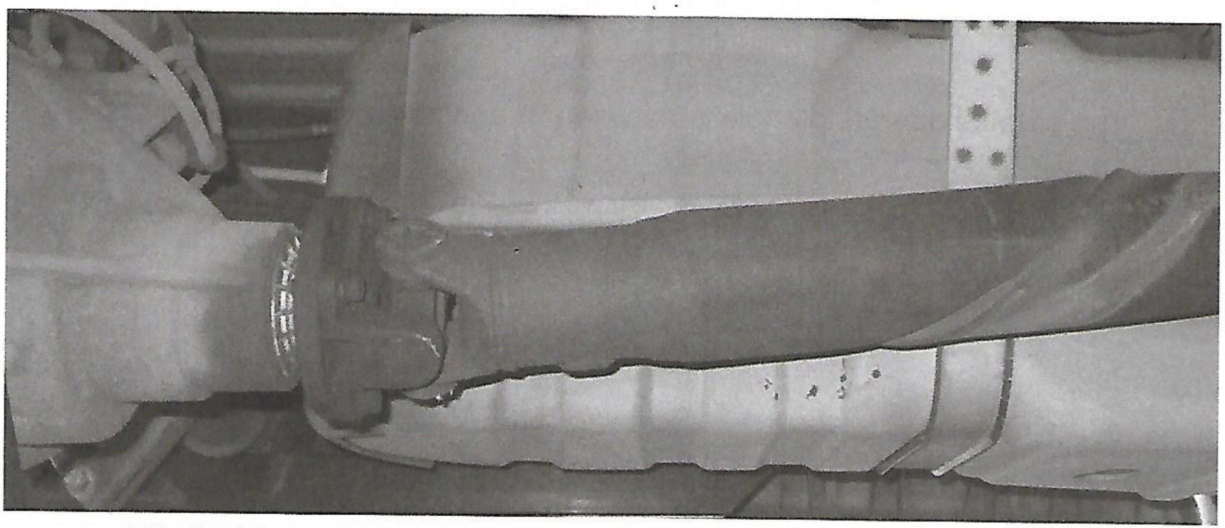


*Note:* *There are a variety of free inclinometer apps available for smart phones!*

## DRIVESHAFT SPEED VIBRATIONS continued...

**Twisted Driveshaft**
Usually an issue found on 4WD vehicle and high performance vehicles. The steel driveshaft is made from relatively thin tubing which achieves its strength through it's highly accurate rolling. However, if the driveshaft is dented as often happens off-road. The strength is significantly reduced and the shaft can twist.

A major twist can be identified visually, while a minor twist can be identified using the driveshaft phasing measurement.



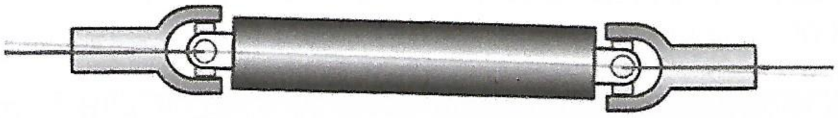
*This Ford F-series has an ECU chip, the extra torque combined with a heavy load meant something had to give!*

*Note:* *Aluminium and carbon fibre driveshafts tend to tear or break rather than bend!*

## DRIVESHAFT SPEED VIBRATIONS continued...

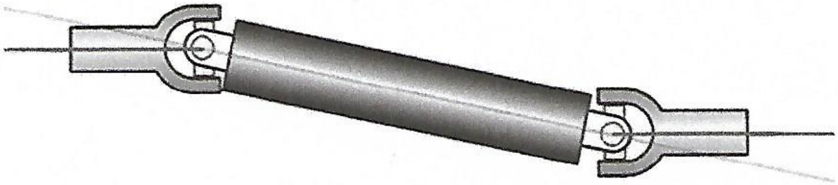
**Driveshaft Angle (U-Joint shafts)**
Unlike CV Shafts, U-Joint shafts have a much a much narrowing angle of operation before excessive D2 vibrations are created. They also require the angle at either end of the shaft to be parallel. These angles should be checked with an inclinometer.

Optimal



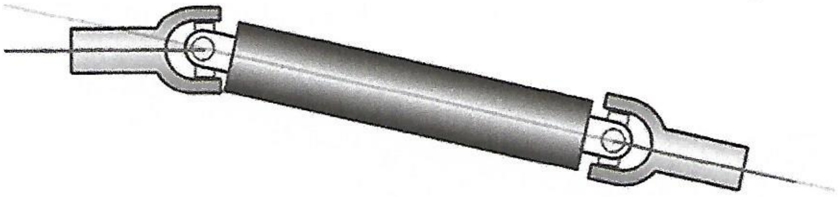
- The optimal operating angle is between 0° and 3° with both yokes parallel

Excessive Angle



- Operating angles greater the 3° will create a D2 vibration that will increase with amplitude as the angle increases.

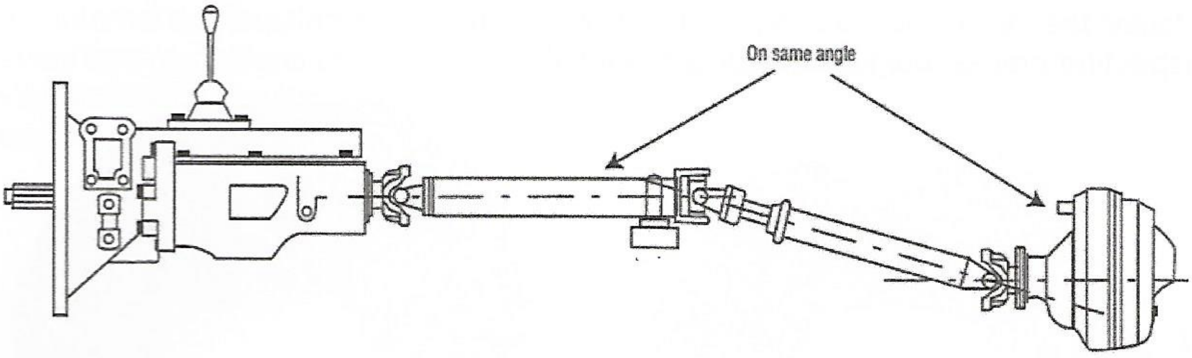
Uneven Yokes



- If the operating angle of the yokes is unequal it will produce a D2 vibration.

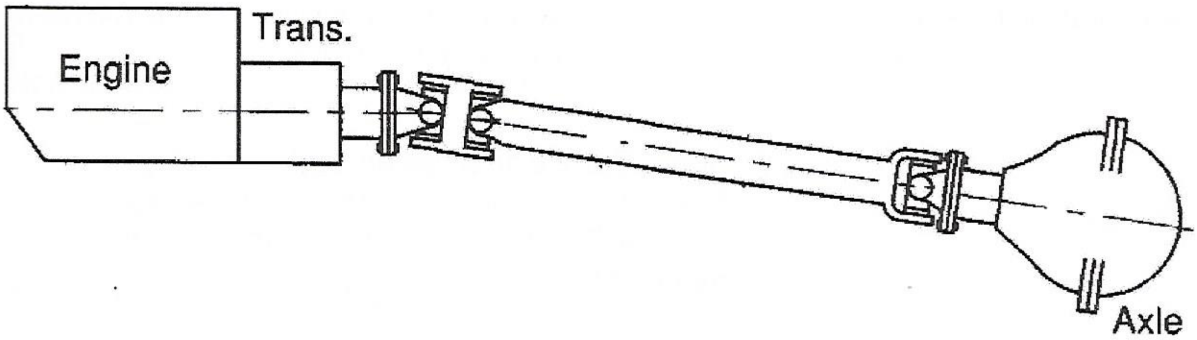
# DRIVESHAFT SPEED VIBRATIONS continued...

Double driveshaft with centre support bearing



- Where a double shaft with centre bearing is used the angle of the first shaft should be parallel with the transmission/transfer which would also be parallel with the differential.

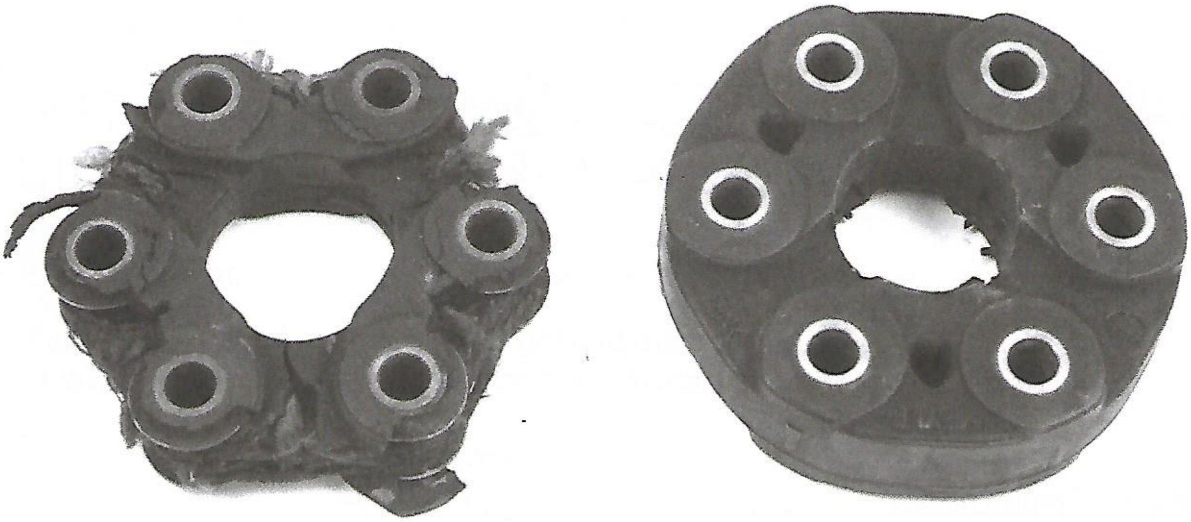
Double Cardan Joints



- Double cardan joints break with tradition and require the differential to be parallel with the driveshaft.

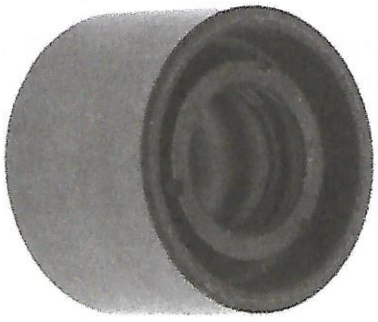
## DRIVESHAFT SPEED VIBRATIONS continued...

**Driveshaft Flex Couplings**
Also referred to as a Flex Disc, Giubo or a Rotoflex.
If faulty, the Flex Coupling can produce a D6 vibration.
Inspect for cracks, bulges and correct orientation.



*When installing ensure the arrows on the outside ring point toward the leg they are attached to, failure to do so will lead to rapid failure of the coupling.*

⚠ *Caution:* *Some BMW's also use an alignment spigot bush, this is often neglected and if damaged will cause a D6 vibration even after the joint has been replaced!*



# ENGINE SPEED VIBRATIONS

## Normal Engine Vibrations

Normal engine vibrations are those produced during the normal combustion of the internal combustion engine (ICE). The four stroke engine completes 1 cycle every two revolutions of the crankshaft, therefore each cylinder creates a half order vibration. When multiplied by the number of cylinders the normal running vibration can be calculated:

- 3 cylinders = E1.5 vibrations
- 4 cylinders = E2 vibrations
- 5 cylinders = E2.5 vibrations
- 6 cylinders = E3 vibrations
- 8 cylinders = E4 vibrations

An E1 vibration is also produced by the crankshaft but should be of a significantly lower amplitude to the combustion vibrations.

4 cylinder engines produce an inherent secondary imbalance. This is counteracted in larger displacement 4 cylinder engines by using two balance shafts that are horizontally phased at 180°. E2.0 vibrations are normal for engines without balance shafts.

Normal engine vibrations are isolated from the passenger compartment by:

- Engine Mountings
- Transmission/Transaxle Mountings
- Exhaust Mountings
- Flexible hoses
- Flexible Cables

## Engine and Trans Mountings

How much of the engine vibrations should be absorbed by the mountings is unclear and contradictory. Most manufacturers do not state a value. Holden tech info states a generic value of 10mG at the drivers seat mounting bolt at idle. The VF V8 commodore tested during the development of this clinic had an E4 of only 11mG when the sensor was placed on the engine side of mounting and of that 11mG only 1.5mG was detected at the drivers seat mounting.

The type of engine (petrol/diesel), number of cylinders and type of engine mounting all affect the amount of vibration that transfers through to the cabin. But as a general rule the engine vibrations should not be detectable in the cabin

# ENGINE SPEED VIBRATIONS continued...

**Exhaust Mountings**

If a normal engine vibration is transferring to the body intermittently, check the exhaust clearance and mountings. The exhaust will grow dramatically as it heats up, extended hard driving will cause greater temperatures and will cause more of the exhaust to heat up. Exhaust systems can grow in length up to 5cm in extreme circumstances.

*Note:* *Exhaust Flex Joints can absorb up to half of the expansion!*

**Flexible Hoses and Cables**

Check the vehicle for hoses and cables that may be the transfer path of a vibration.

**Single Cylinder Misfire**

Regardless of how many cylinders a single cylinder misfire will always produce a E0.5 vibration. Carry out engine diagnostics to determine if this is the cause.

**Camshaft/Phaser Faults**

The Camshaft and phasers (where fitted) turn at half the crankshaft speed. While camshafts being out of balance are extremely rare it is not as unlikely for a camshaft phaser to fail producing an E0.5 vibration.

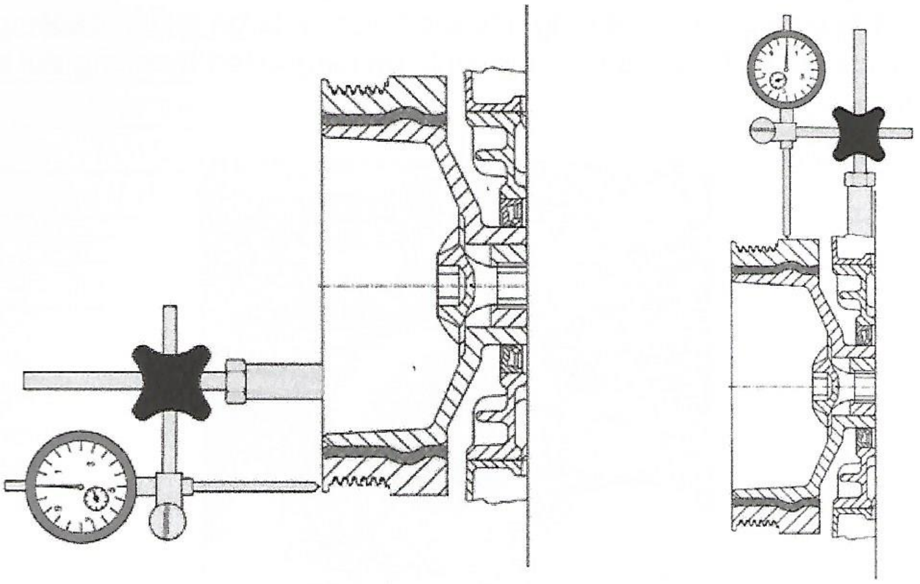
Test for:

1. Camshaft DTC's
2. Camshaft angle PID's
3. Actuation test on phasers
4. Faulty tensioner
5. Stretched timing chains
6. Check camshaft angles with an oscilloscope while driving the vehicle under the conditions that generate the E0.5 vibration.

## ENGINE SPEED VIBRATIONS continued...

### Harmonic Balancer failure

Often caused by long storage time, the load of the drivebelt by the automatic (or even manual) tensioner will compress the dampener rubber on one side.



*Harmonic Balancer axial runout (left) and radial runout (right)*

- Check the pulley runout (radial and axial) should not exceed 0.50mm

### Flywheel and Clutch balance

If you have diagnosed an E1.0 vibration that is believed to be excessive and cannot be attributed to the Harmonic Balancer the next logical step is the flywheel and clutch. Because of the labour time involved and because the clutch is a wear item balancing this unit would be uneconomical when compared to a replacement unit (new components are balanced during manufacture). The flywheel should be machined and balanced or if a dual mass flywheel is used it should be replaced.

### Driveplate and Torque Converter balance

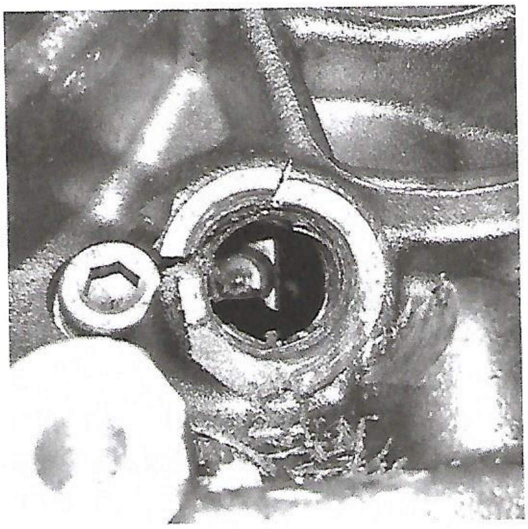
If you have diagnosed an E1.0 vibration that is believed to be excessive and cannot be attributed to the Harmonic Balancer the next logical step is the driveplate and torque converter. Because of the labour time involved and relatively low cost of new items balancing these items would be uneconomical when compared to a replacement unit (new components are balanced during manufacture).

### Balance shaft timing - Primary Imbalance

Any engine with an odd number of cylinders on any bank (I3, I5, V6 and V10 ) will produces a primary imbalance (E1.0 vibration). Many of these engines employ a countershaft to counteract this imbalance. Checking the timing of these shafts will confirm if this is the cause of an E1.0 vibration.

## ENGINE SPEED VIBRATIONS continued...

**Crankshaft balance**
Crankshaft balance changing after installation is very rare but not impossible. One such scenario saw the plug for the crankshaft locking pin on a Audi incorrectly installed (a longer bolt was fitted instead of the plug). When the crankshaft was turned over it fowled on the webbing and dislodged a large piece, causing a crankshaft imbalance. This scenario can only be diagnosed by ruling out all other possibilities.



**Other vibrations**
Other vibrations can be caused by driven accessories. It is possible to calculate the vibration order by dividing the diameter of the crankshaft pulley by the diameter of the driven pulley for each accessory.

Accessory vibrations can mostly be proven by removing the accessory drive belt.

Some examples below:

| Name | Diameter | Order |
|---|---|---|
| Crankshaft Pulley | 150mm | E1.00 |
| Water Pump | 120mm | E1.25 |
| Alternator | 50mm | E3.00 |
| Power Steering Pump | 120mm | E1.25 |
| A/C Compressor | 140mm | E1.07 |
| Tensioner Pulley | 70mm | E2.14 |
| Idler Pulley | 70mm | E2.14 |

*Note:* *These are random examples, but follow typical principles!*

# SPECIAL SERVICE TOOLS

| Name | Part Number |
|---|---|
| Kincrome Dial Indicator with Magnetic Base | 5604 |
| Sidcrome Dial Indicator | SCMT26110 |
| Sidcrome Magnetic Base | SCMT26109 |
| Starrett Roller Contact Kit for Dial Indicator | 25W |
| Inclinometer App | Free via App Store (Google Play / iTunes) |
| Pico Scope | PICO4425ADV |
| Pico NVH 3-Axis Kit | NVH-3A |
| Mongoose ISO/CAN Lead | MONCAN |
| Treysit Sirometer | 670156 |

# NOTES

### Section ii

# Dual Mass Flywheels

## CONTENTS

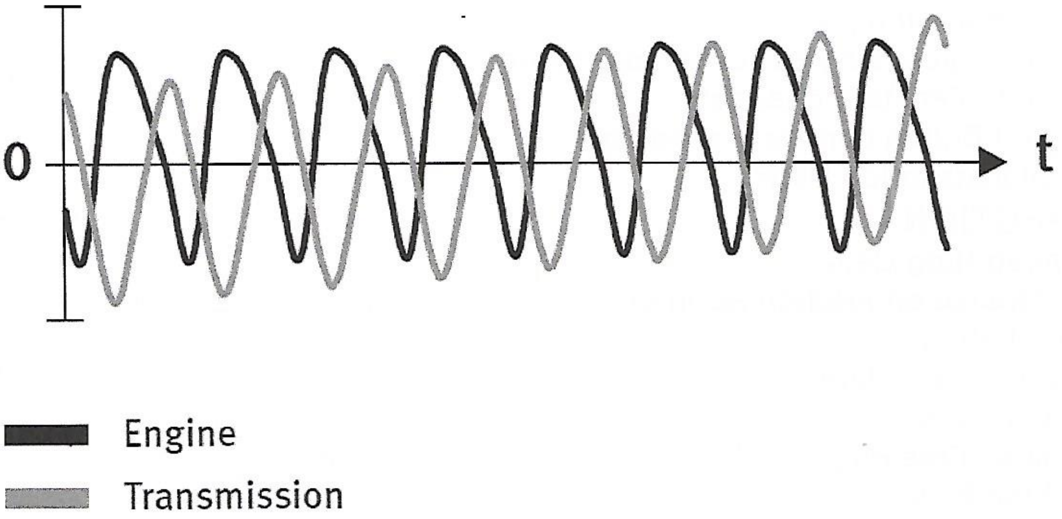
OVERVIEW 46
DMF VARIATIONS 47
Basic DMF 47
DMF with inner (flange) dampener 48
DMF with friction pack 49
DMF with secondary pendulum dampener 50
DMF with planetary gear set 51
DMF and Clutch complete assembly 52
Special Installation DMF's 53
INSPECTION 54
Damaged Ring Gear 54
Oil or Grease on Friction Surface 54
Thermal Stress 54
Friction Pack Failure 55
Contamination 55
Rotational Free Play 56
Axial Free Play 57
Bearing Failure 58
Torsion Spring Load 59
DIAGNOSIS 60
Engine tuning modifications 60
Engine and Transmission Mountings 61
Cleaning the friction surface 62
INSTALLATION TIPS 62
Transportation Plug 62
Torque To Yeild Bolts 63
SINGLE MASS FLYWHEEL CONVERSION 63
SPECIAL SERVICE TOOLS 63
NOTES 64

## OVERVIEW

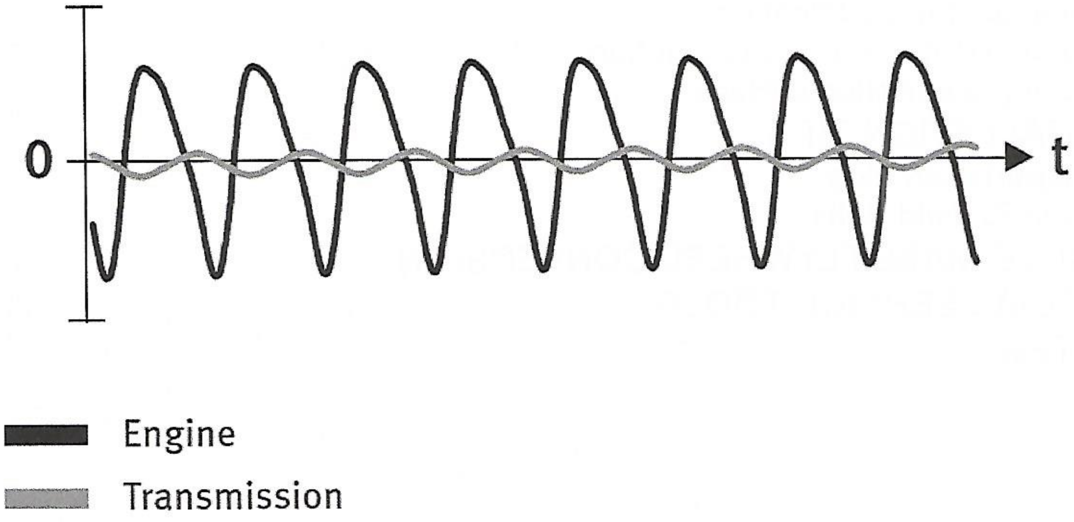
The development and application of Dual Mass Flywheels (DMF's) began in the early 1990's. Their ability to absorb the engines combustion vibrations made them almost necessary for any passenger car fitted with a diesel engine. Lower engine speeds means that greater variations in the engine crankshaft speed exist, requiring a greater travel in the torsional absorber.

The advantage of a DMF is best attributed to the amount of mass on the gearbox side of the torsion springs Solid Mass Flywheel (SMF) only has the weight of the clutch hub and the drive load. Even the simplest DMF has the Secondary Flywheel, Clutch Plate, Clutch Cover and the drive load.

Better dampening has allowed for lower viscosity gearbox oils which increase the efficiency of the transmission unit.



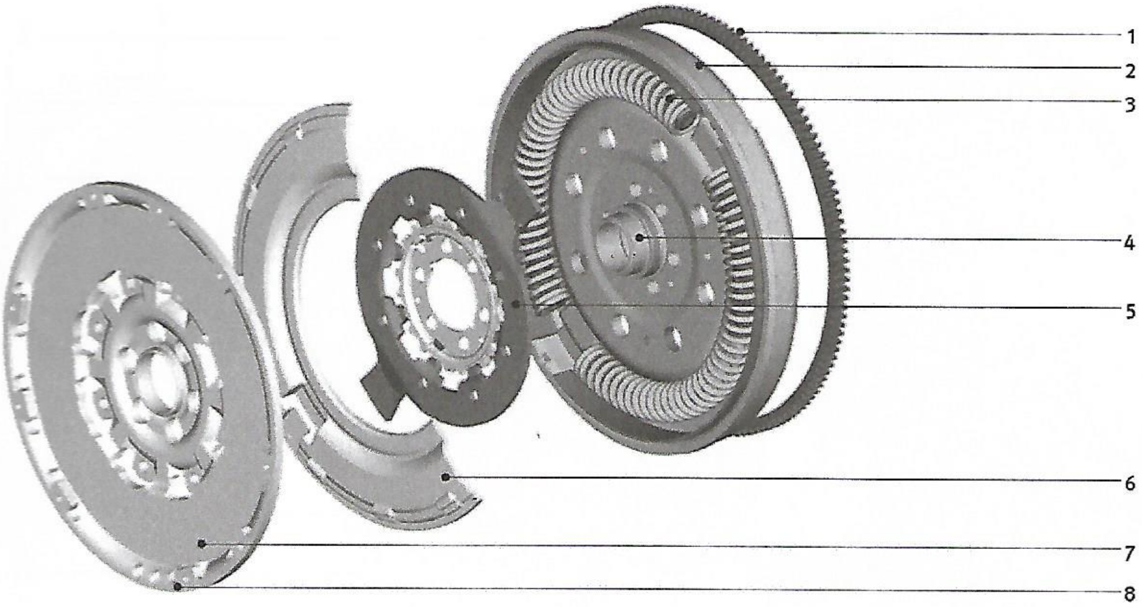
*Vibration transfer with SMF*



*Vibration transfer with DMF*

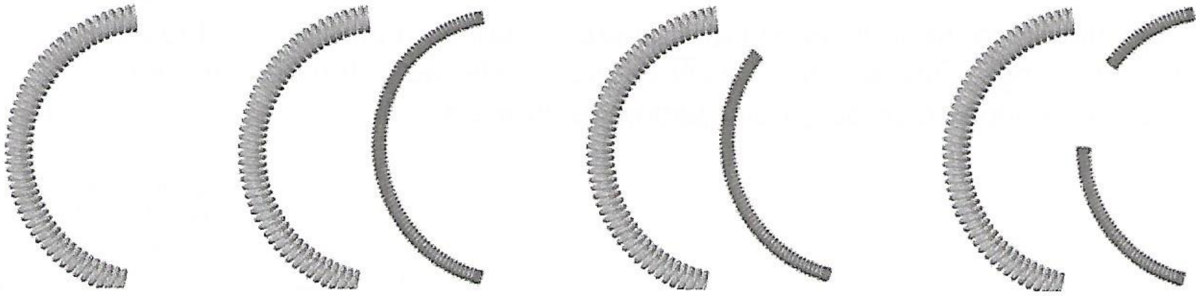
# DMF VARIATIONS

## Basic DMF



| Basic DMF | | | |
|---|---|---|---|
| 1 | Ring Gear | 2 | Primary Mass |
| 3 | Torsion Springs | 4 | Bearing |
| 5 | Drive Plate | 6 | Primary Cover (sectioned) |
| 7 | Friction Surface | 8 | Secondary Mass |

The torsion springs can be single, dual parallel, dual two-stage or dual three-stage

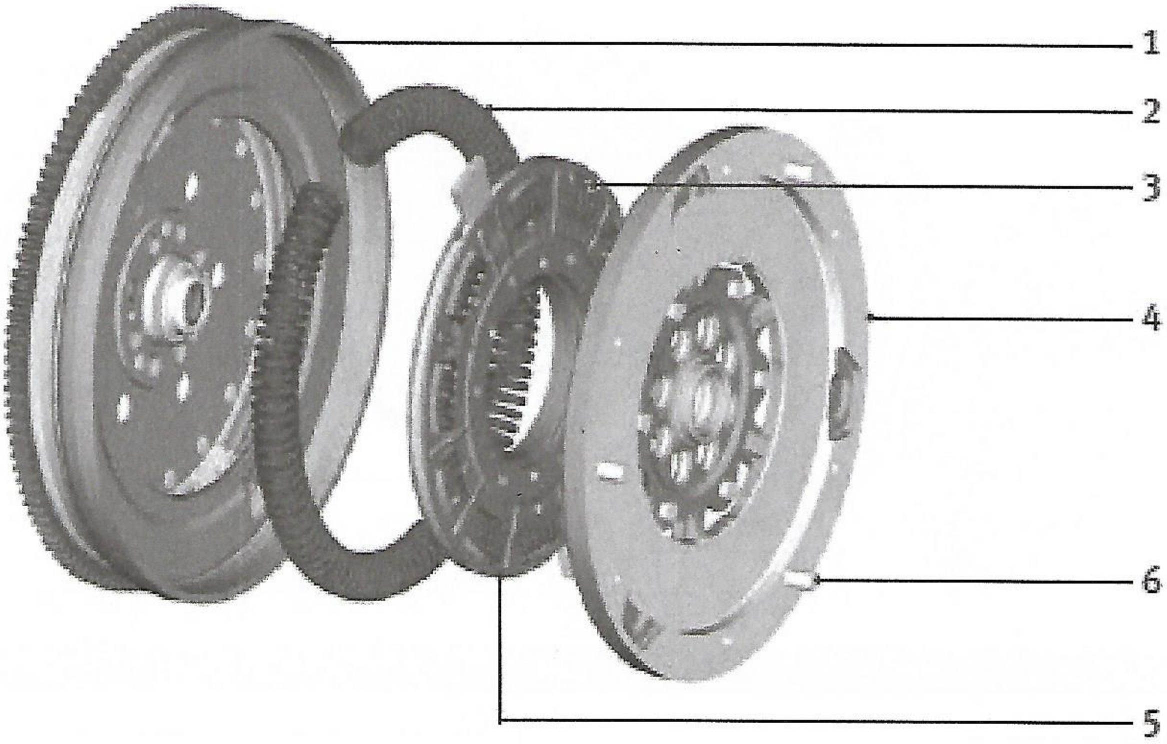


*Single* *Dual Parallel* *Dual two-stage* *Dual three-stage*

* Idle speed is important for vibrations low eng speed. will change the frequency dynamics which can show up as vibrations

## DMF VARIATIONS continued...

### DMF with inner (flange) dampener

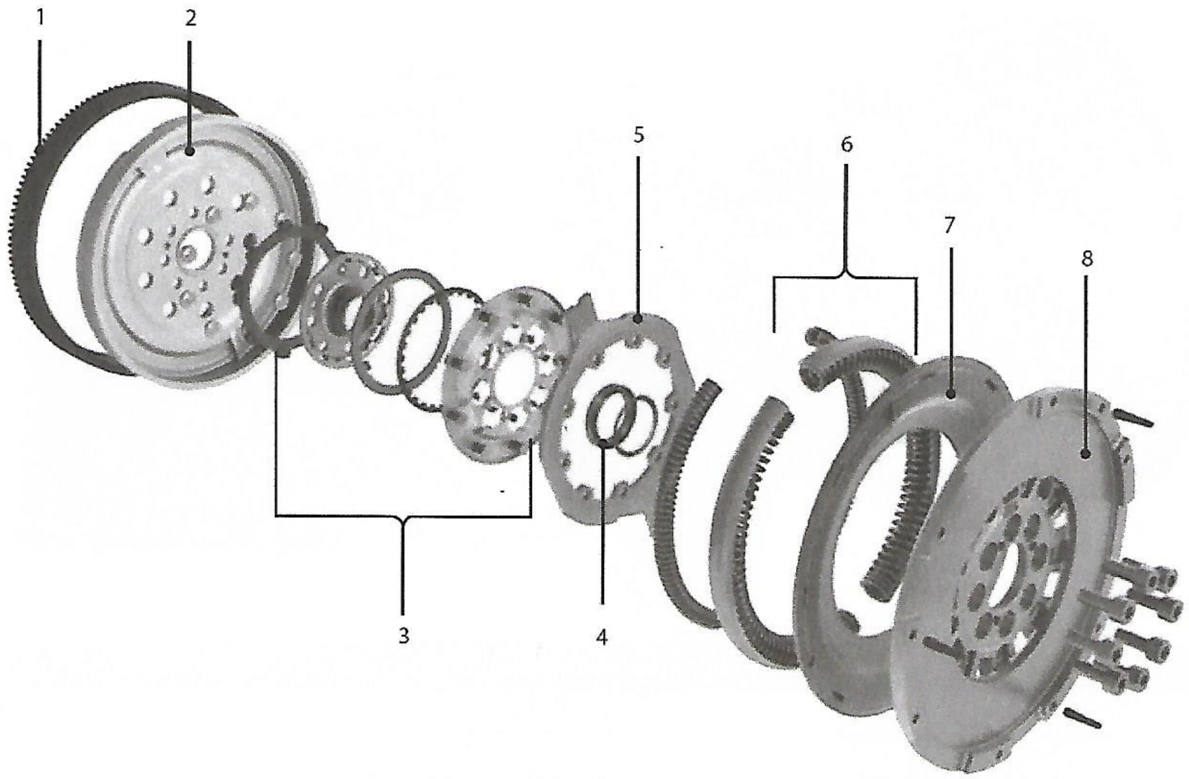


| DMF with inner dampener | | | |
|---|---|---|---|
| 1 | Primary Mass | 2 | Outer Torsion Springs |
| 3 | Drive Plate | 4 | Secondary Mass |
| 5 | Inner Torsion Springs | 6 | Clutch Cover Dowel |

The inner flange springs are set at a different natural frequency than the outer torsion springs. This reduces the vibrations transferred to the transmission. The inner springs provide greater tuning parameters

# DMF VARIATIONS continued...

## DMF with friction pack

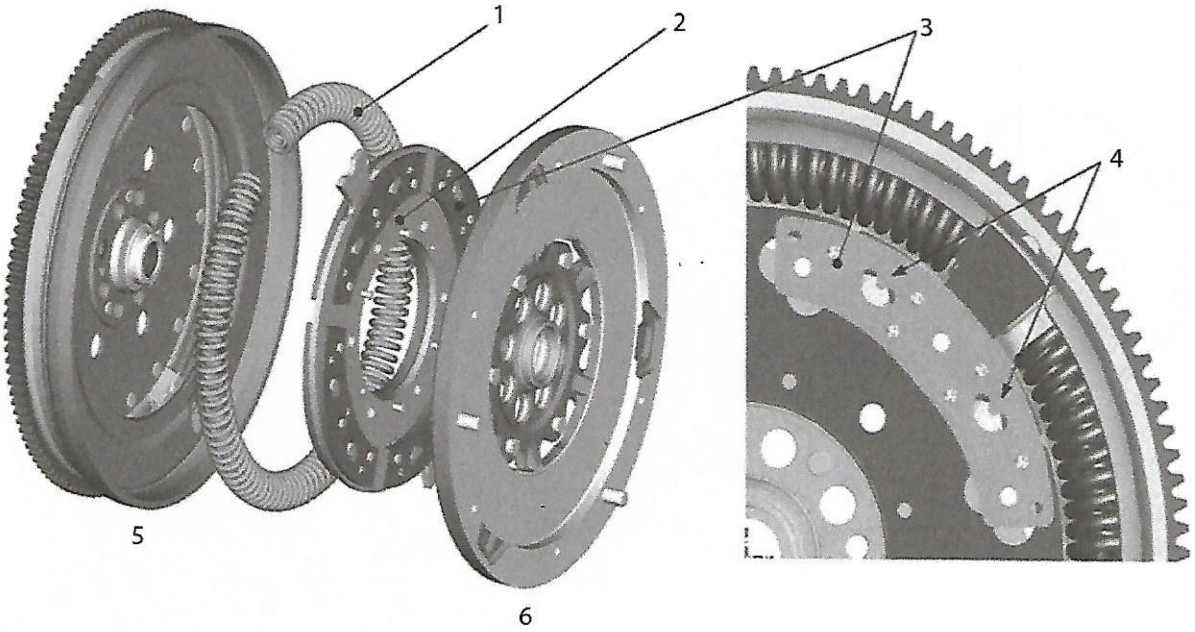


| DMF with secondary pendulum dampener | | | |
|---|---|---|---|
| 1 | Ring Gear | 2 | Primary Mass |
| 3 | Friction Pack | 4 | Bearing |
| 5 | Drive Plate | 6 | Torsion Springs |
| 7 | Primary Cover | 8 | Secondary Mass |

The friction pack delays the initial load required before the torsion springs are activated, especially during engine start up. Essentially another tuning mechanism.

# DMF VARIATIONS continued...

## DMF with secondary pendulum dampener

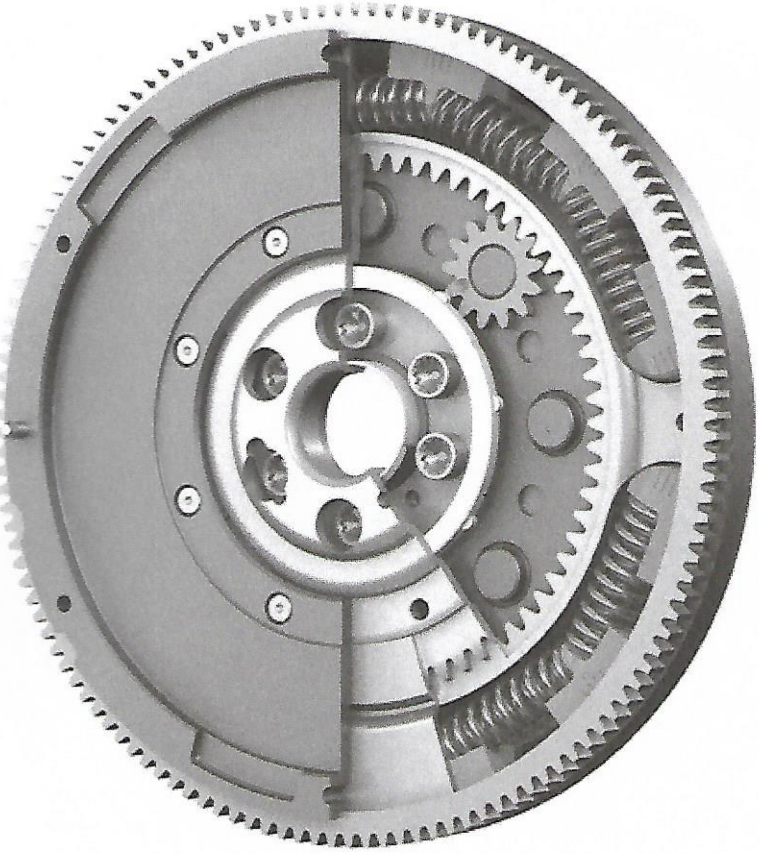


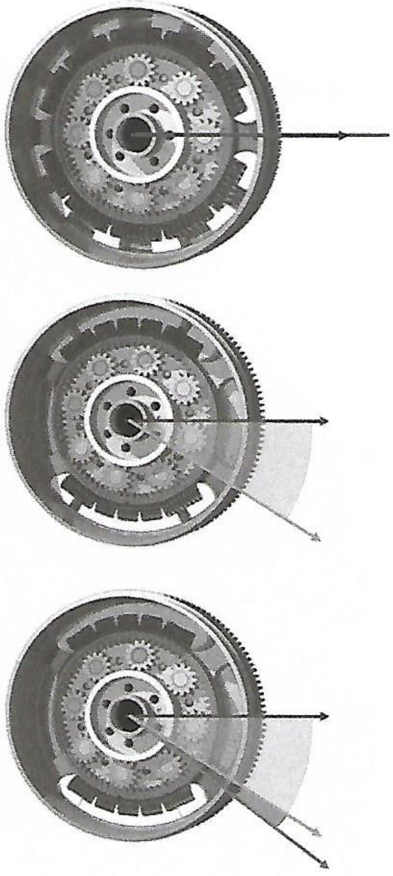
| DMF with secondary pendulum dampener | | | |
|---|---|---|---|
| 1 | Torsion Springs | 2 | Flange |
| 3 | Pendulums | 4 | Pendulum Rollers |
| 5 | Primary Mass | 6 | Secondary Mass |

Pendulums actually counteract the rotational vibrations rather than simply absorbing..This provides greater vibration absorbance as well as reduced strain on the torsion springs.

## DMF VARIATIONS continued...

### DMF with planetary gear set

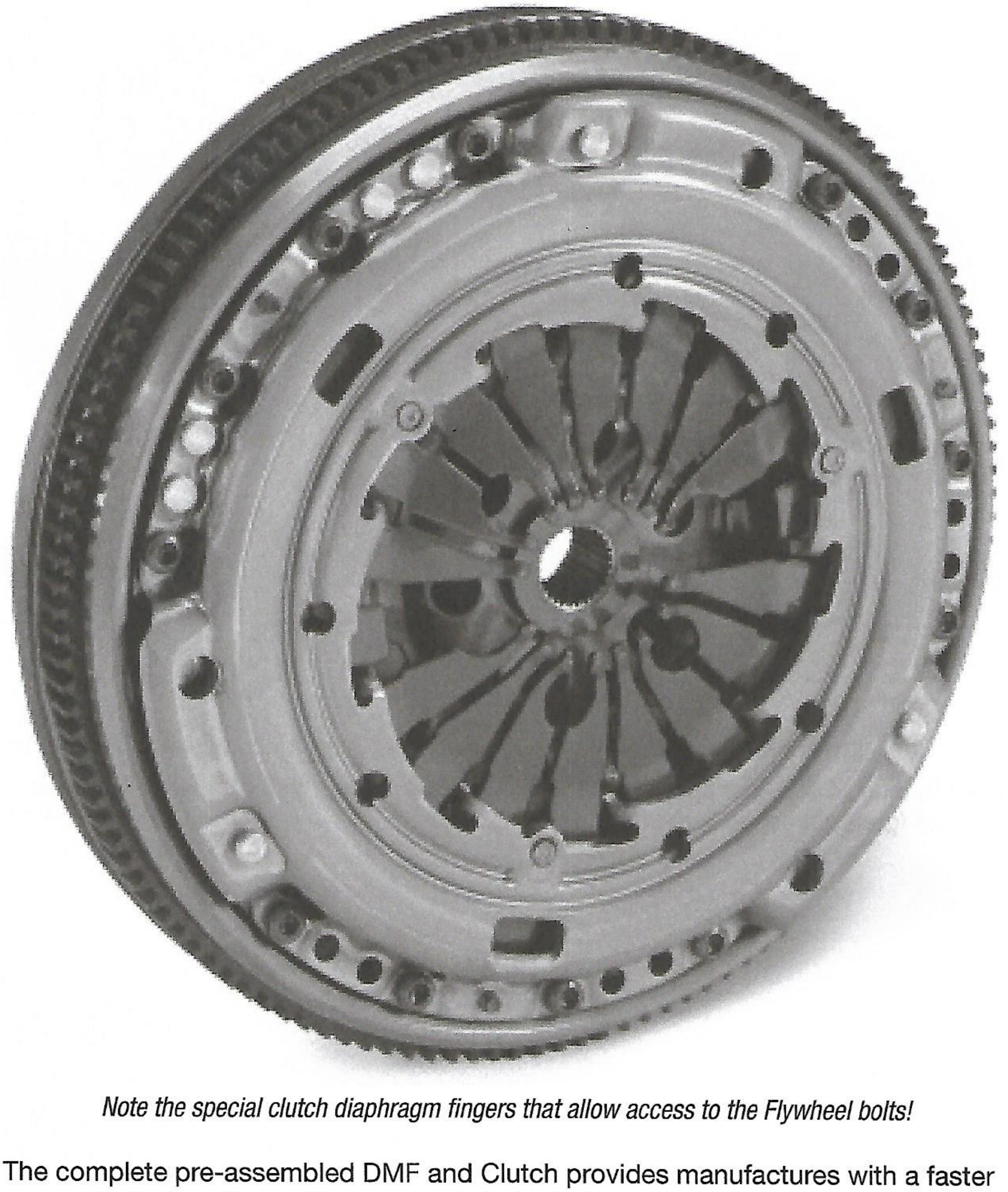




The planetary DMF was specifically designed for compact vehicles with 4 cylinder engines (greatest secondary vibrations).

## DMF VARIATIONS continued...

### DMF and Clutch complete assembly



*Note the special clutch diaphragm fingers that allow access to the Flywheel bolts!*

The complete pre-assembled DMF and Clutch provides manufactures with a faster assembly. It also allows all components to be balanced together as a single unit. Also provides for simpler replacement process with greater control of balancing.

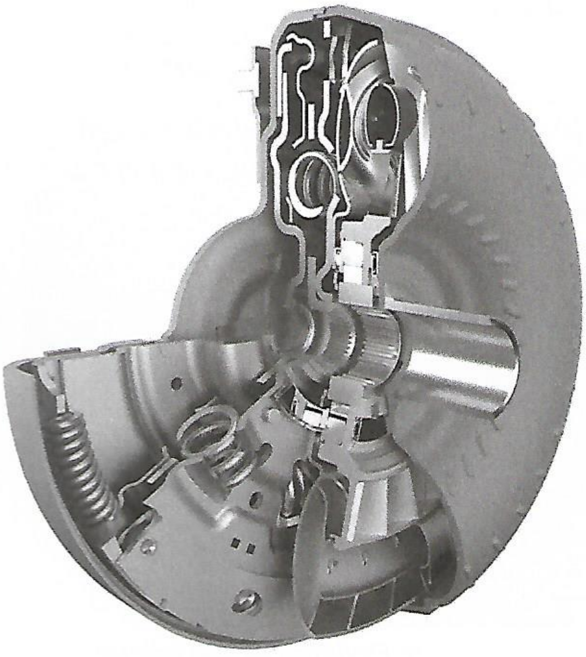
## DMF VARIATIONS continued...

**Special Installation DMF's**
There are further variants of the DMF to suit the physical space they are to be fitted into, as well as the type of transmission.

These DMF's have been redesigned to suit the Volkswagen Group (VAG) vehicles fitted with a Direct Shift Gearbox (DSG).

The DMF for the VAG DSG's does not require a friction surface because it is integrated into the dual clutch unit. Instead it has a large toothed locating ring the attaches the clutch unit housing.

Similarly, the wet clutch DSG's have their friction surface submerged in fluid within the dual clutch unit. The clutch unit housing connects to the DMF via splines.



Another variant sees the DMF integrated into the Torque Converter of an Automatic Transmission.

Many Lock-up Torque Converters use a small amount of slip to prevent torsional vibrations transferring through to the transmission. The Centrifugal Pendulum Vibration Absorber (CPVA) is currently in use on US spec Colorado 2.8L diesel. It provides smoother operation and allows for lock-up at engine speeds below 1,500rpm.

## INSPECTION

Unless there are special circumstances it is recommended that the DMF should be replaced whenever the clutch is replaced. Both LuK and Sachs which are the two largest manufacturers of DMF's state that they must be fully inspected before reusing and they must not be used for more than two clutch changes.

However, in reality: it is often the DMF that fails before the clutch. DMF's wear due to different factors than the clutch plate and diaphragm spring. So you cannot base the serviceably of the DMF on clutch wear alone.

Ensure that the vehicle owner is fully aware that if the DMF was to fail after the clutch kit was replaced, the entire job would need to be re-done and at the very least a new clutch friction plate should also be required.

If you do wish to measure the DMF, the following procedure outlines the tests required:

### Damaged Ring Gear

As with any flywheel inspection, ensure that there is no significant damage to the Ring Gear. As the engine will stop on the compression stroke, there will be sections of the Ring Gear with greater wear than others.

- If excessive wear is found the DMF must be replaced, the Starter Motor should also be replaced as the two mesh together.

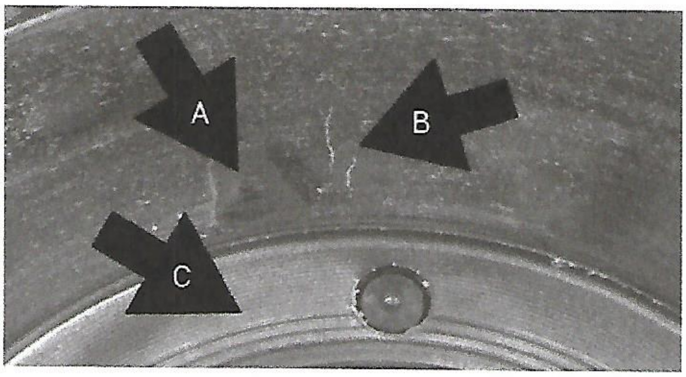
### Oil or Grease on Friction Surface

If oil or grease has contaminated the DMF it must be replaced.

*Note:* *A small amount of oil on the engine side is acceptable if it can be wiped away without submerging the DMF!*

### Thermal Stress

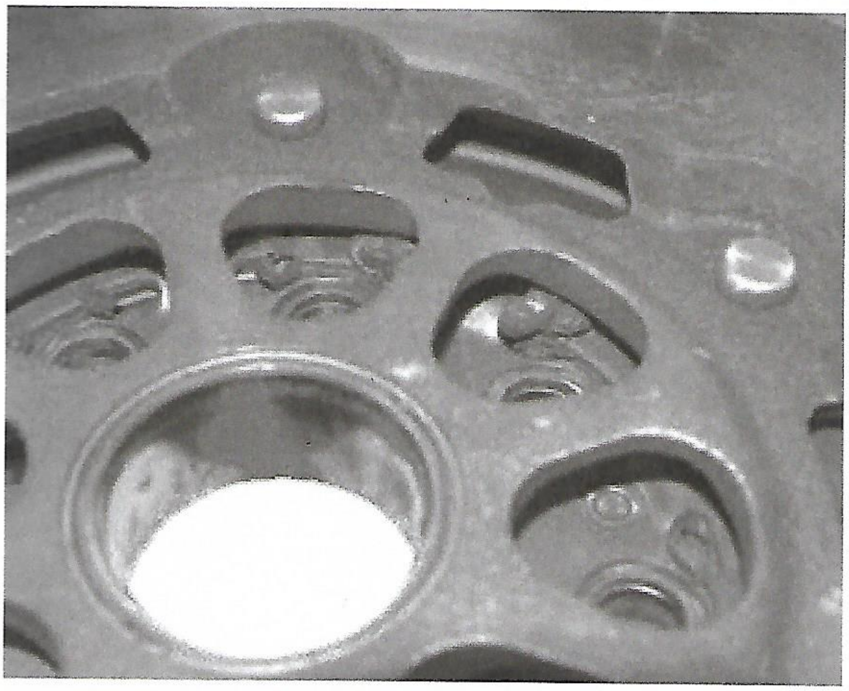
As with any flywheel, thermal stress on the friction surface must be addressed before fitting a new clutch plate. Look for cracks and discolouration. As it is not possible to re-surface a DMF it must be replaced.



*A and C: Discolour due to excessive heat* *B: Fissures lead too cracks!*

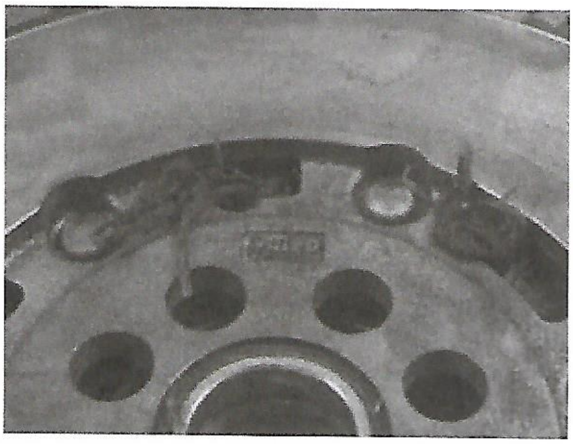
## INSPECTION continued...

**Friction Pack Failure**
Extreme overheating of the clutch can transfer to the friction pack causing overheating and failure.



*Resins and adhesive from this friction pack have melted*

**Contamination**
These DMF's have been contaminated by the shreds of fibrous material from failed clutch plates. Washing the DMF would remove necessary lubricants from the torsion springs and other internal components. Replacement of the DMF is required.



## INSPECTION continued...

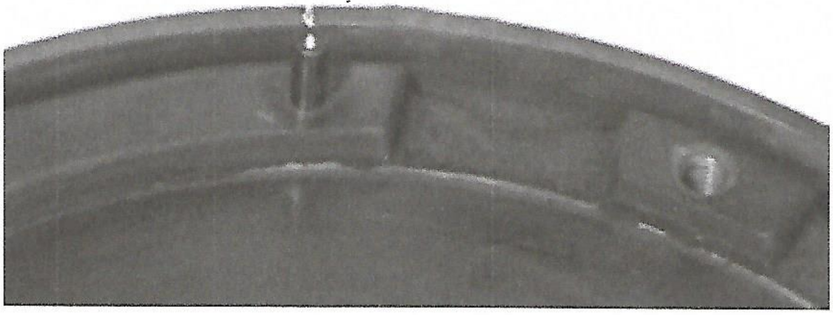
**Rotational Free Play**
The amount of rotational free play is the best indicator for assessing the condition of the torsion springs. The test is to measure the unloaded free play, so regardless of manufacturers recommendations no special service tools are required.

Procedure:

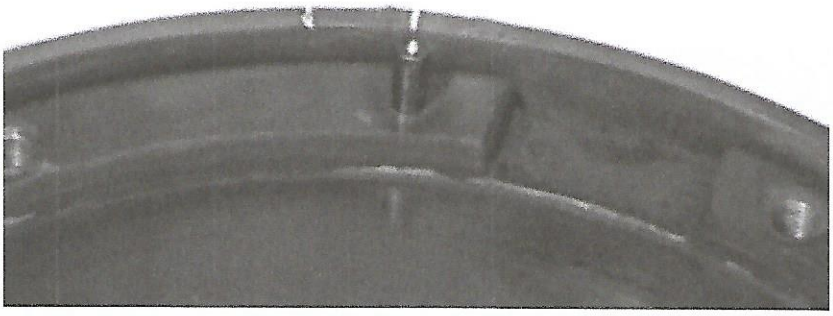
1. Rotate the secondary mass anti-clockwise as far as possible by hand and then slowly release

*Note:* *DMF's fitted with friction packs will require a small amount of force to overcome the friction, other than this the procedure is the same!*

2. Mark this point with a paint pen (or similar)



3. Rotate the secondary mass clockwise as far as possible by hand and then slowly release.
4. Mark this point with a paint pan (or similar)



5. Count the total number of teeth on the Ring Gear
6. Count the number of teeth between the two paint marks
7. Calculate the free play:

*360 / total teeth of Ring Gear x teeth of free play = degrees of free play*
*360 /180 x 3 = 6°*

- Maximum free play varies from 2° to 30° so check the vehicle specifications.

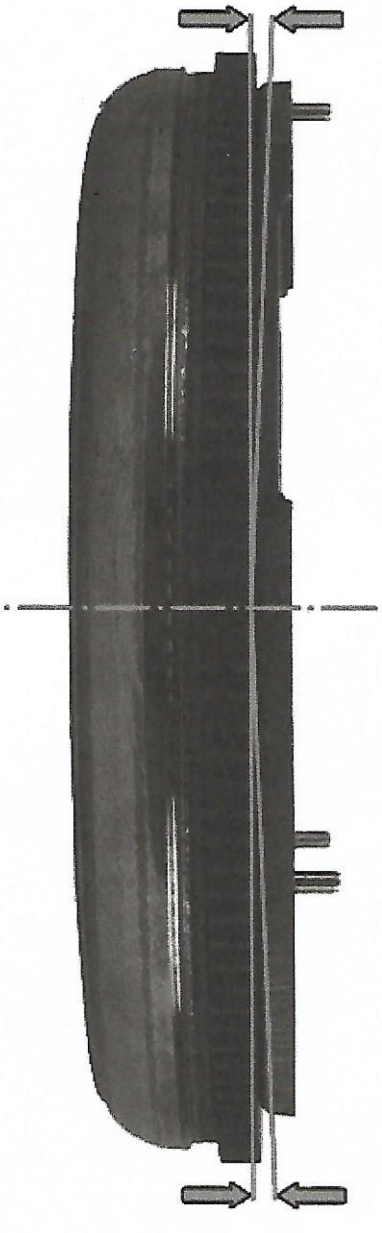
## INSPECTION continued...

### Axial Free Play

A DMF has a certain amount of Axial Free Play to allow for the bending moments of the crankshaft that occur with each combustion stroke.

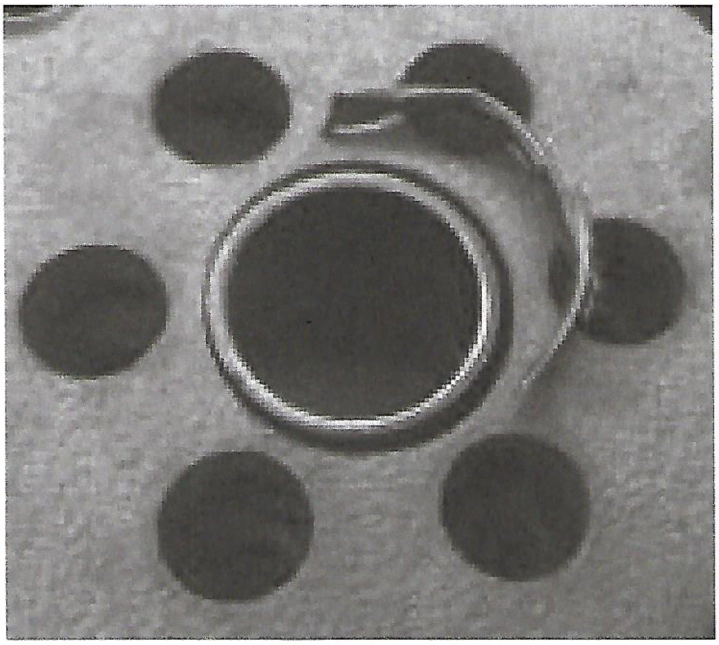
Measure the free play with a Dial Indicator The amount of free play depends on the type of bearing used:

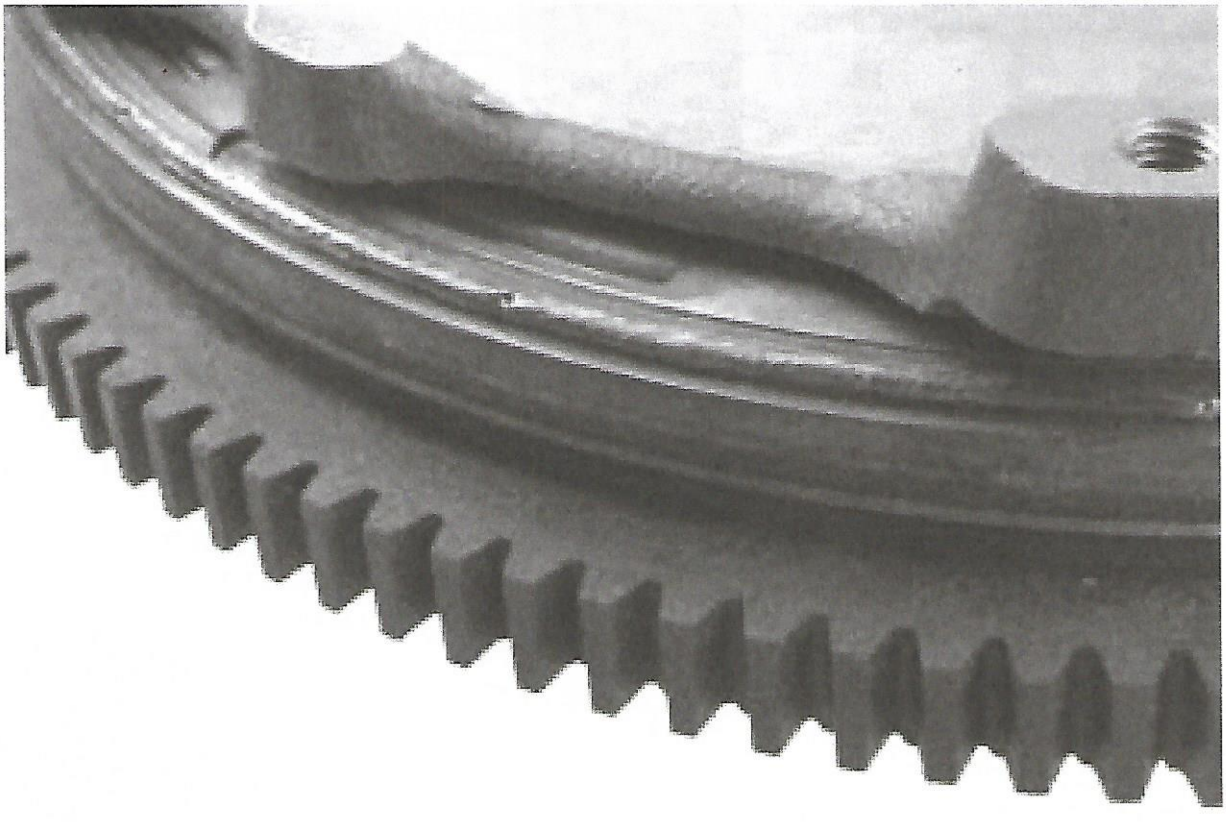
- Ball Bearing: up to 1.6mm
- LuK - Plain Bearing (Bushing) up to 2.9mm
- Valeo - Plain Bearing (Bushing) up to 2.6mm



## INSPECTION continued...

**Bearing Failure**
The bearing which separates the primary and secondary masses may fail if subjected to excessive heat or after extended service. Excessive wear can be identified by checking the Axial Run Out and in severe cases it is possible to see witness marks where the primary and secondary masses have been making contact.





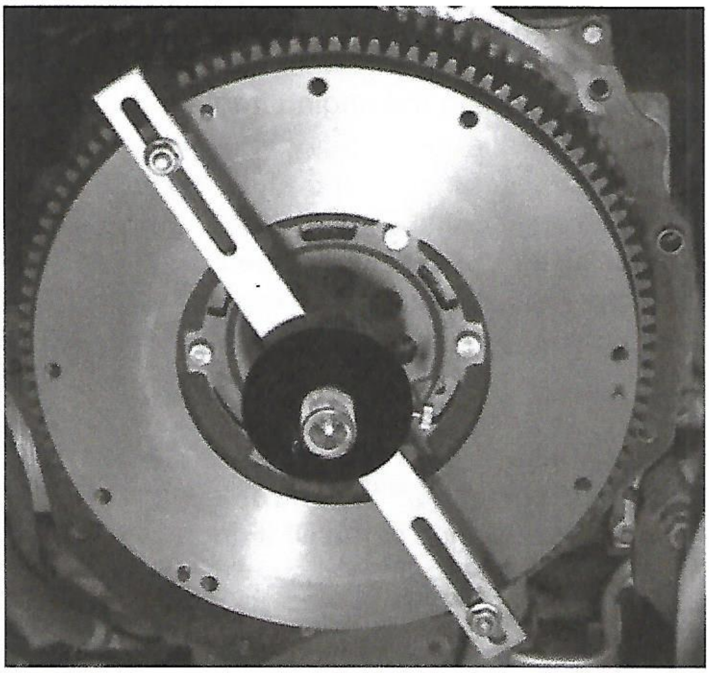
*Check for evidence of contact between the primary and secondary masses*

# INSPECTION continued...

**Torsion Spring Load**

The torsion spring load is not a common test for DMF's. However, this procedure is a requirement for the Holden RG Colorado and possibly others and is a reminder to the importance of checking the model specific specifications.

1. Mount the special testing tool across the clutch mounting holes so that the 1/2 drive connection is centred



2. Lock the flywheel
3. Turning clockwise, use a torque wrench to apply a small amount of pressure to take up the free play
4. Mark this point with a paint pen
5. Measure 42° to the right of this mark, if you don't have a degree gauge use the following formula

*Total teeth on Ring Gear / 360 x angle required in degrees = angle in teeth*
*180 / 360 x 42° = 21 teeth*

6. Turn the secondary mass clockwise and measure the force required to reach the 42° mark
7. Turning anti-clockwise, use a torque wrench apply a small of pressure to take up the free play
8. Mark this point with a paint pen
9. Measure 42° to the left of this mark
10. Turn the secondary mass clockwise and measure the force required to reach the 42° mark

- The force required to achieve 42° must be between 140Nm and 230Nm

## DIAGNOSIS

Diagnosing a DMF failure while assembled in the vehicle is difficult and primarily rests on the ruling out of all other possible causes.

As with all components the DMF has a natural (resonant) frequency. When the engines frequency matches the natural frequency of the DMF the secondary mass will resonate to its full extremities causing the flange to hit the angle stops, which produces a knocking noise.

The DMF is manufactured with a natural frequency of 7.5Hz to 15Hz depending on the applications keeping it just below engine idle speed. However, there will be a period of time during start up where the engine frequency matches the DMF and knocking will be produced.

Other causes of excessive engine and DMF resonating:

- Weak battery causing slower cranking speed
- Failing starter motor causing slower cranking speed
- Low idle speed
- Ignition timing
- Pre-ignition
- High engine loads at idle
- Releasing the clutch without sufficient throttle
- Stiffening of the torsion springs in the DMF increasing its natural frequency up to or above idle speed

In all other functions the DMF is designed to absorb the torsional vibrations without unpleasant vibrations and noise transferring to the cabin. The following list provides other factors that should be ruled out before diagnosing DMF failure.

**Engine tuning modifications**
If the engine have been 'chipped' or had other performance enhancements it will now be operating above the designed torque output that the DMF was designed to operate. This may cause the DMF to reach its maximum torque and rotational limits during normal driving resulting in excessive noise, vibration and the likelihood of premature DMF failure. Engine tuning usually changes two factors that directly impact the DMF, throttle angle delay is removed and maximum torque is increased.

The best method of addressing this is to remove the engine modifications and replace the DMF if it has failed. If the engine enhancements are necessary for the owner of the vehicle a heavy duty SMF retrofit should be performed because it is unlikely that a new DMF will operate normally.

*Caution:* *This will have a detrimental effect on the rest of the drivetrain and may cause excess noise and vibration . Premature failure of other driveline components is also likely!*

## DIAGNOSIS continued...

**Engine and Transmission Mountings**
Ensure that the mountings are in a serviceable condition. The DMF is designed to absorb the engines combustion vibrations which are in the order of half of the number of cylinder (due to the combustion occurring on every other stroke of the piston). These vibrations are normal engine vibrations that are also isolated from the cabin by the engine and transmission mountings, exhaust hangers and flexible cables and hoses.

Further diagnosis can be achieved by carrying out vibration diagnosis. Check that the undesirable vibration is in the correct order, the vibration order of a faulty DMF will be:

- 2nd Order Engine Speed (E2) for 4 cylinder engines
- 3rd Order Engine Speed (E3) for 6 cylinder engines
- 4th Order Engine Speed (E4) for 8 cylinder engines

Operate the vehicle under the conditions where the vibration is at its greatest amplitude, measure the vibration at both the powertrain and chassis side of each mounting and ensure sufficient dampening.

*Note:* *As there are no specifications for this test it may help to compare against a known good vehicle.*

*See: Normal Engine Vibrations in the Vibration Diagnostics chapter for further tests.*

If excessive noise and vibration is of the correct order and cannot be attributed to mountings or other paths for normal engine vibrations to transfer to the cabin, the DMF is a likely candidate.

# INSTALLATION TIPS

There are many different vehicle specific installation requirements, so always refer to model specific installation instructions. Following are some general tips for those who have not fitted many DMF assemblies:

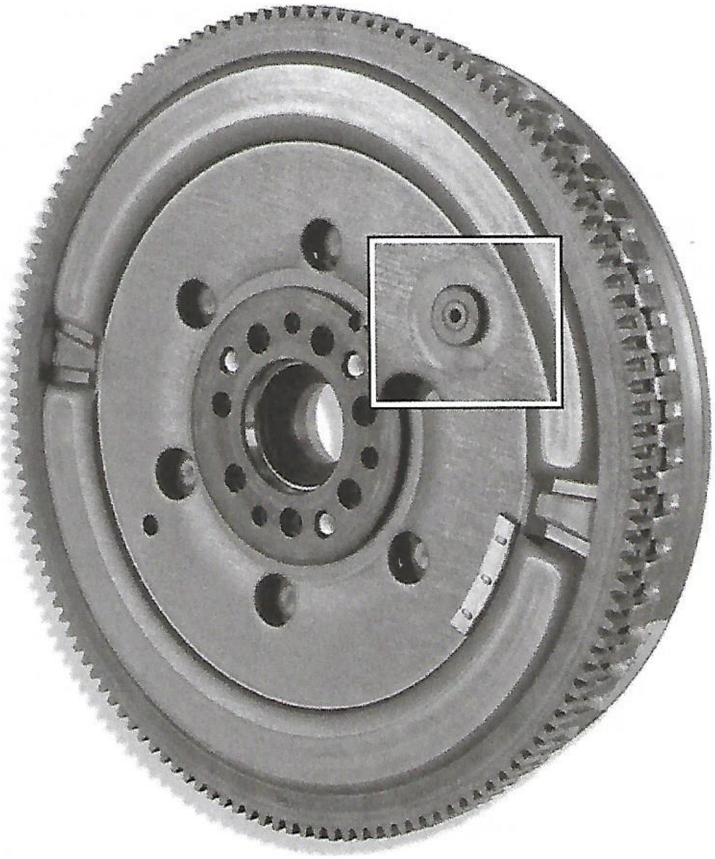
**Cleaning the friction surface**

Do not submerge or spray the DMF with solvents or cleaning products. The DMF has special lubricants on the torsion spring guides. These lubricants control how the DMF varies its absorption at different engine speeds. Dissolving the lubricants might cause the DMF to act as a solid mass above a certain RPM causing adverse vibration and transmission wear.

If cleaning of the DMF friction surface is required use an alcohol based product such as brake-clean or acetone, apply a small amount of cleaner to a clean lint free rag and wipe the friction surface as required.

**Transportation Plug**

Some DMF's are supplied with a transportation plug which prevents the two masses from moving during transportation. The plug is designed to shear offer when the engine is started with the two halves remaining in place.



*New DMF with transportation plug*

*Caution:* *Because the flywheel is balanced with the plug in situ it must not be removed during installation!*

## INSTALLATION TIPS continued...

**Torque To Yeild Bolts**
The significant majority of DMF's are fitted with single use Torque To Yield (TTY) Bolts. Unless stated otherwise always assume that the bolts are single use.

## SINGLE MASS FLYWHEEL CONVERSION

Under normal circumstances the DMF should never be converted to a SMF. The gearbox has be designed to operate behind a DMF and the increased vibrations of a SMF conversion will reduce the transmissions service life. There may be special circumstances where a vehicles engine output has been increased beyond the operating range of the DMF leaving no option but to convert to SMF, in these circumstances the transmission should also be modified to meet the greater torque load.

## SPECIAL SERVICE TOOLS

| Name | Part Number |
|---|---|
| Dual Mass Flywheel Test Kit | ET8544 |

# NOTES

## Section iii

# 4WD Switching and Control

## CONTENTS

INTRODUCTION 66

DESIGN 68

COMMON FAULTS 69

Learned Parameters Lost or Corrupted 69

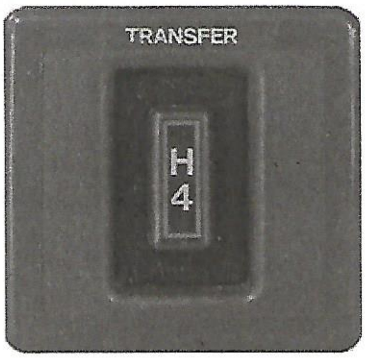
Actuator Gearbox Failure 69

GENERAL DIAGNOSIS 70

NOTES 74

# INTRODUCTION

For many of us in the Australian and New Zealand automotive industry the move from lever to switch activation of the transfer case began in 1988 when Toyota released the revamped 62 series Land Cruiser that came with an 'H4' switch for the electronically controlled vacuum actuated centre differential lock.



Since this time it has evolved and spread to almost every 4WD on the market. Most importantly for manufacturers it removes the transfer lever from the cabin and the noise and vibrations it carried.

Todays systems all use electromechanical actuators attached to the transfer. The actuators include either switches or position sensors for feedback and diagnostics.

2WD
4H
PUSH
4LO

*Nissan Navara*

2H
4H
PUSH
4L

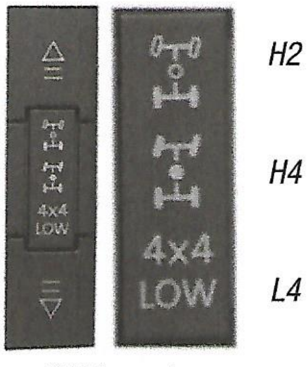
*Isuzu MU-X*

H2
H4
-PUSH-
L4

*Toyota Hilux*

*Holden Colorado*

*Ford Ranger*



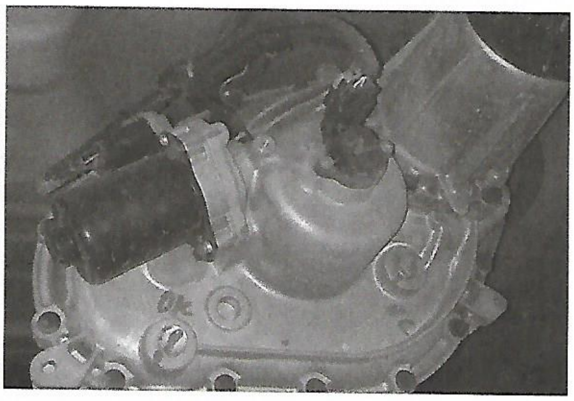
*VW Amarok*

*Note:* *Even though the VW Amarok has a different style of switch the options are the same!*

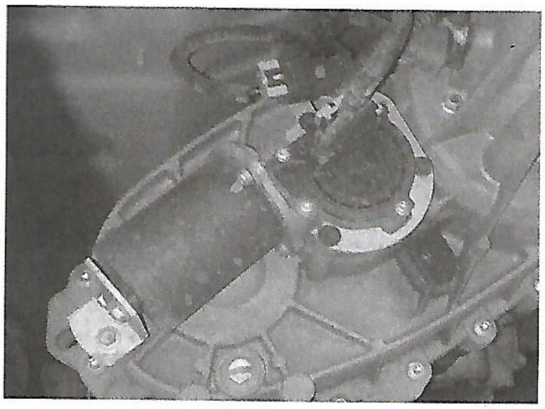
## INTRODUCTION continued...

Similarly the Transfer Case actuators are also remarkably similar

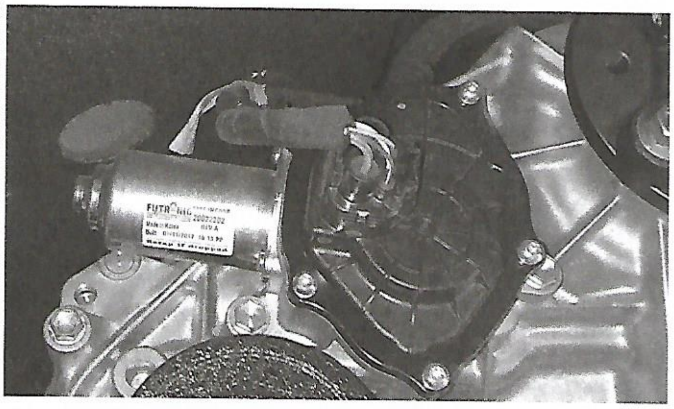
*Toyota HiLux GUN126R*



*Nissan Navara NP300*

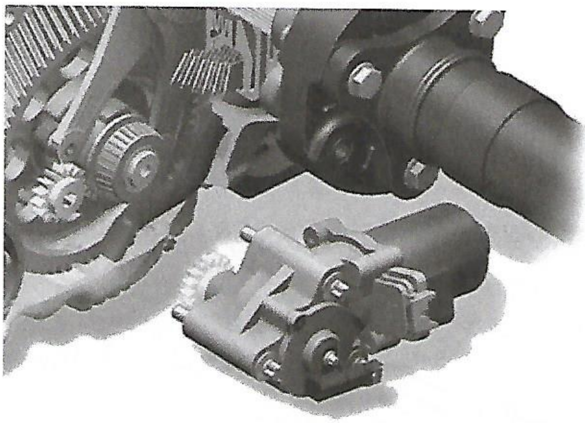


*Holden RG Colorado*



*Ford Ranger PX MkII / Mazda BT50 UR*

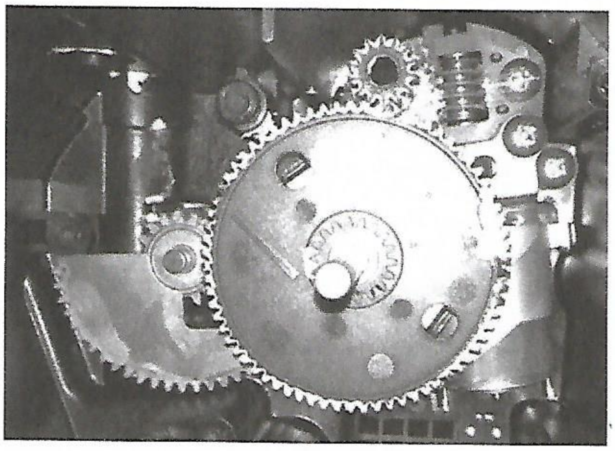
*VW Amarok 2H*



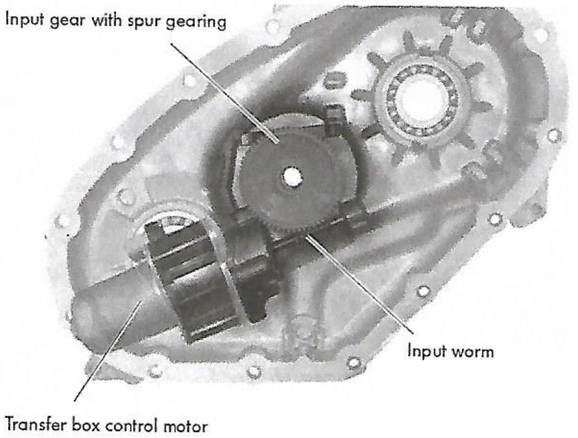
*BMW X-drive*

## DESIGN

All systems use a Duty Cycle controlled motor that uses a worm gear to drive a gearbox in order to provide the torque required to move the selectors.

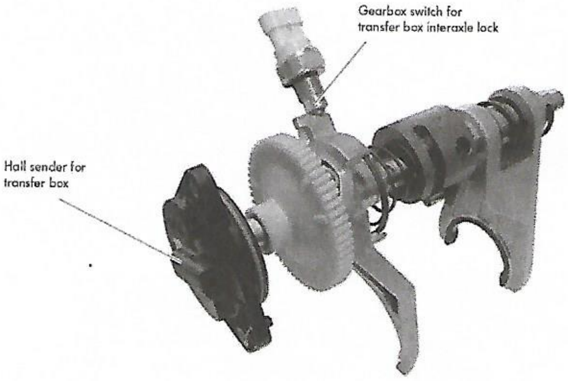


*Gearbox of a HiLux Actuator*

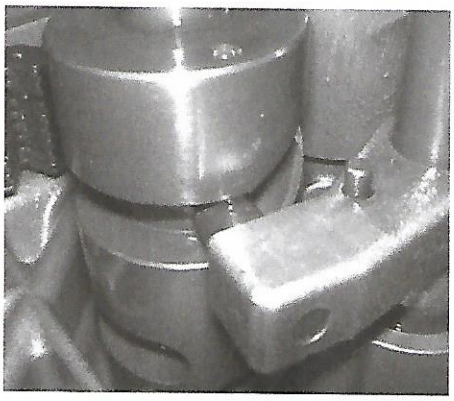

Input gear with spur gearing
Input worm
Transfer box control motor

*Worm drive and gear of an Amarok*

The Shift Hub converts the rotary motion of the gearbox to axial movement of the Shift Fork.

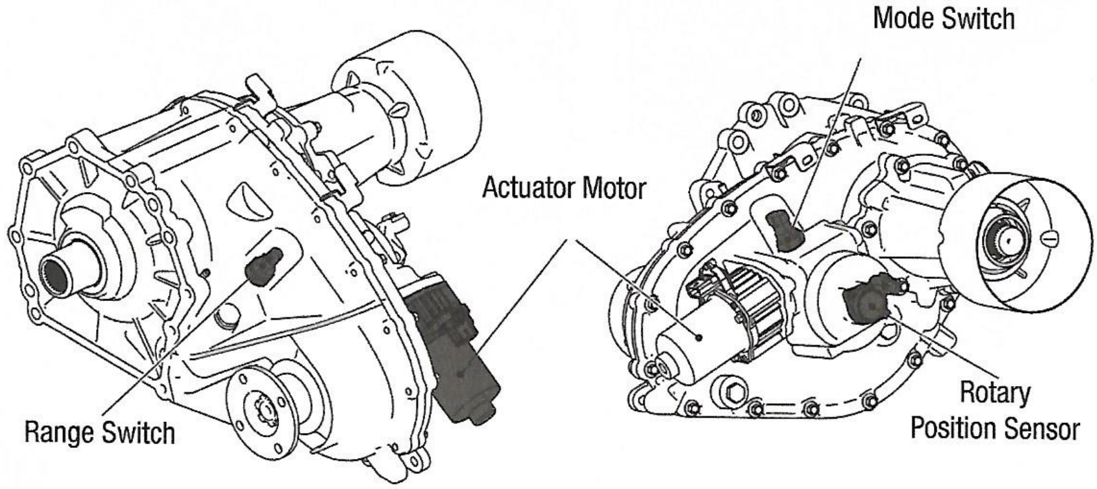

Gearbox switch for transfer box interaxle lock
Hall sender for transfer box

*Amarok Shift Fork with Switch and Sensor*



*Ranger Shift Hub and Fork*

Either Switches, Sensors or a combination of both provide feedback to the ECU.


Mode Switch
Actuator Motor
Range Switch
Rotary Position Sensor

*Switches as Sensors of the Nissan Navara NP300*

* Relearns can fix alot of intermittant issues

## COMMON FAULTS

### Learned Parameters Lost or Corrupted

The most common of all faults is the loss of the learned parameters, this was more problematic on earlier vehicle models with electromechanical actuators. Current model vehicles have either reduced or completely eliminated the need to re-learns. The cause of the data loss is typically due to loss of power supply or disconnection of the connectors. Data corruption can occur when the driver does not follow the correct engagement procedure (such as switching to low range while moving) and confuses the ECU.

For Nissan's ATX90A transfer case fitted to some Y61 Patrol's and R51 Pathfinder's there are a few steps:

Configuration

If you are replacing the Transfer ECU, Transfer Actuator or the complete Transfer Assembly you must configure the Actuator to the ECU using a letter that is cast in the bottom of the Actuator and a complex decoding chart from the factory manual.

Lock Sensor Position Learning

The ECU monitors the locking of the Centre Differential (bypassing the Multiplate Clutch). If the switch or ECU are replaced or if the data is lost of corrupted you must first clear the Lock Sensor memory and then perform a re-learn.

Rotary Position Sensor Learning

The Rotary Position Sensor monitors the gear driven by the actuator. If the sensor or ECU are replaced or if the data is lost of corrupted you must first clear the Lock Sensor memory and then perform a re-learn.

Fluid Deterioration Re-Learn

As the centre differential uses a multiplate clutch, the ECU is programmed to alter the fluid pressures as the fluid deteriorates. If the fluid is replace you must reset this parameter.

⚠ *Caution:* *Most Nissan Transfer Cases require 40,000km oil changes. However, the ATX90A is "Filled for Life" and uses very expensive fluid. DO NOT accidently drain it out!*

### Actuator Gearbox Failure

When the actuator has a mechanical failure it is usually a result of water ingress or simply wear and tear. The defining symptom of this fault is that when turning the ignition ON a mechanical clicking or grinding noise is evident from the Transfer Case region for a few seconds and is usually closely followed by the illumination of a 4WD warning lamp or message.

# GENERAL DIAGNOSIS

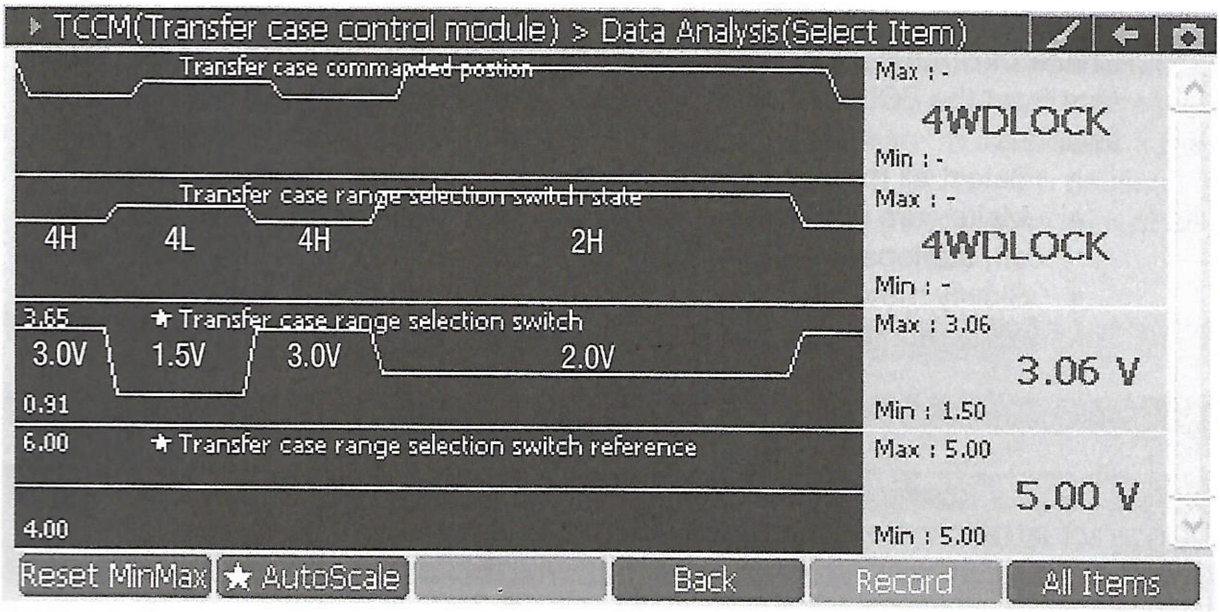
1. **Visual Inspection**
   Check that the Actuator, Switches, Sensors and Wiring are all intact

2. **Battery and Charging Voltages**
   The Actuator draws a reasonable amount of current and will therefor be one of the first items affected by low voltage

3. **DTC's**
   Are there any DTC's that may be related to the fault, remember the Transfer ECU needs data from other systems to function.
   Check for DTC's related to:
   - Transfer Control System
   - CAN Bus communication errors
   - Vehicle Speed signal
   - Auto Trans Range Switch
   - Clutch Position Switch
   - Brake Pedal Position Switch
   - Steering Angle Sensor

4. **Transfer Switch PID's**
   Check the Transfer ECU parameters (Scan Tool Data) focusing on the data sent from the Switch to the ECU (the drivers request)
   - Select all the Transfer Switch parameters so they are all visible at once
   - Make sure all of the vehicle requirements are met (eg. in neutral, brake on, stationary, etc...)
   - Slowly move the Transfer Control Switch through all of the positions while monitoring the values of the ECU on the Scan Tool Data

## GENERAL DIAGNOSIS continued...



▸ TCCM(Transfer case control module) > Data Analysis(Select Item)

Transfer case commanded postion — Max : - 4WDLOCK Min : -

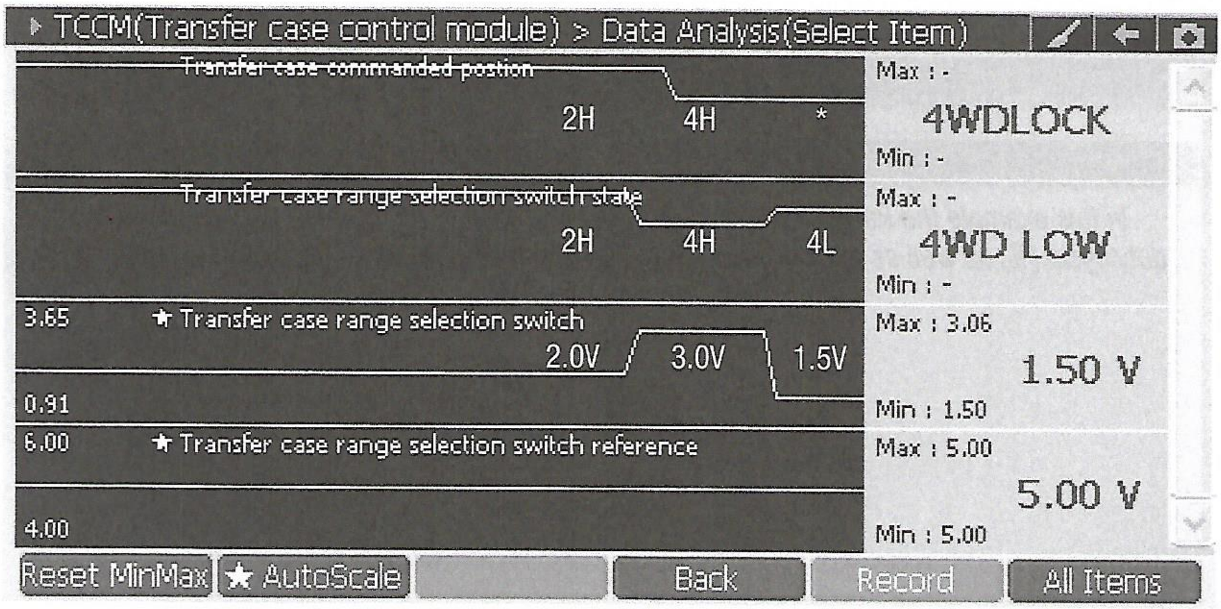
Transfer case range selection switch state — Max : - 4WDLOCK Min : -

★ Transfer case range selection switch — Max : 3.06 3.06 V Min : 1.50

★ Transfer case range selection switch reference — Max : 5.00 5.00 V Min : 5.00

4H
4L
4H
2H
3.65
3.0V
1.5V
3.0V
2.0V
0.91
6.00
4.00
Reset MinMax
★ AutoScale
Back
Record
All Items

*In this example from a Holden RG Colorado:*
*the third parameter shows the voltage received from the switch,*
*the second parameter shows the ECU's interpretation of the switch signal and*
*the first parameter shows the ECU command based on the input.*



▸ TCCM(Transfer case control module) > Data Analysis(Select Item)

Transfer case commanded postion — Max : - 4WDLOCK Min : -

Transfer case range selection switch state — Max : - 4WD LOW Min : -

★ Transfer case range selection switch — Max : 3.06 1.50 V Min : 1.50

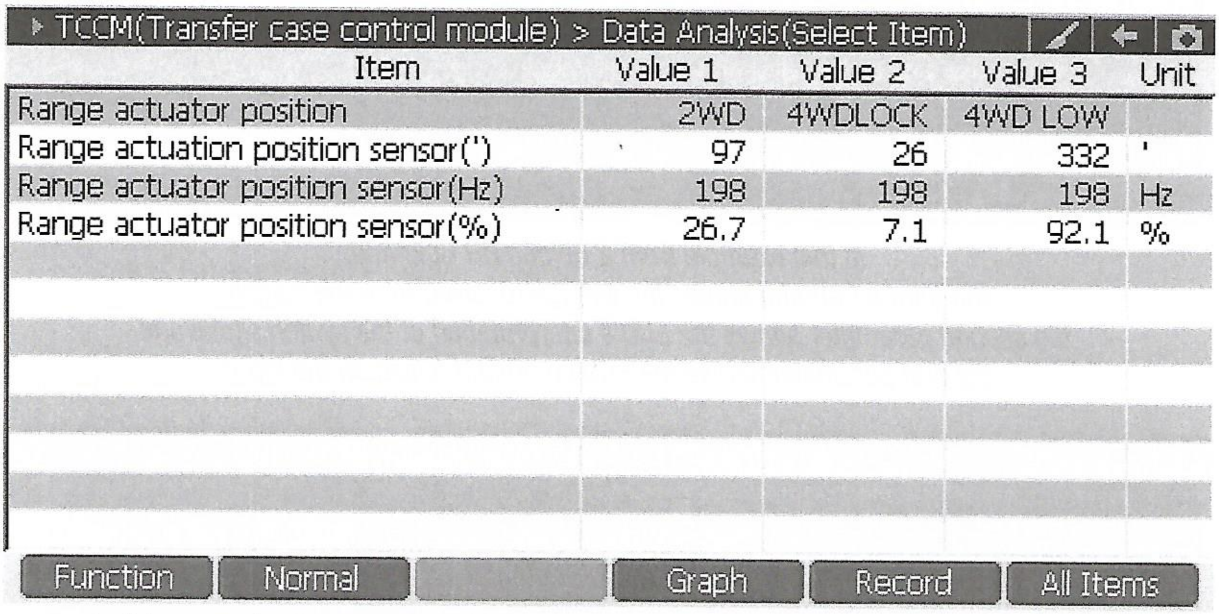
★ Transfer case range selection switch reference — Max : 5.00 5.00 V Min : 5.00

2H
4H
*
2H
4H
4L
3.65
2.0V
3.0V
1.5V
0.91
6.00
4.00
Reset MinMax
★ AutoScale
Back
Record
All Items

*In this earlier example from the same RG Colorado a faulty brake light switch is preventing the engagement of 4L (one of the required parameters). It is clearly shown that the signals are being received by the ECU but the command has not been made.*

## GENERAL DIAGNOSIS continued...

5. **Transfer Case PID's**
   Check the Transfer ECU parameters (Scan Tool Data) focusing on the data sent from the ECU to the Actuator and all of the feedback sensors and switches
   - Select all the Transfer Case parameters so they are all visible at once
   - Make sure all of the vehicle requirements are met (eg. in neutral, brake on, stationary, etc...)
   - Slowly move the Transfer Control Switch through all of the positions while monitoring the values at the ECU



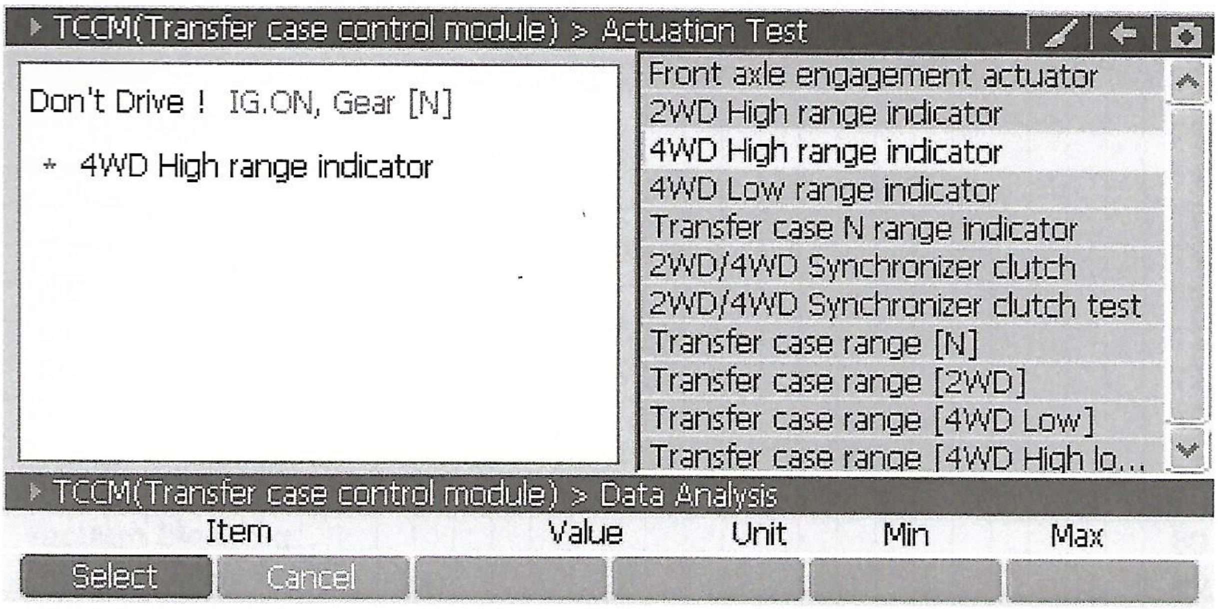
▸ TCCM(Transfer case control module) > Data Analysis(Select Item)

| Item | Value 1 | Value 2 | Value 3 | Unit |
|---|---|---|---|---|
| Range actuator position | 2WD | 4WDLOCK | 4WD LOW | |
| Range actuation position sensor(') | 97 | 26 | 332 | ' |
| Range actuator position sensor(Hz) | 198 | 198 | 198 | Hz |
| Range actuator position sensor(%) | 26.7 | 7.1 | 92.1 | % |

*In this example the Range Sensor is providing feedback to the ECU and are displayed in duty cycle (%) as well as the calculated angle (°) of the selector shaft based on the duty cycle.*

## GENERAL DIAGNOSIS continued...

6. Transfer Case Actuation Tests
   Test the problematic components by applying actuation tests. These tests override many of the input parameters (except those that are listed in the test procedure). This will help to identify if the Transfer System has a fault or if the issue is that a critical input signal is not being received. If a system passes the Actuation Test but fails during steps 4 and 5, have a very close look at all of the parameters as described in step 3.


TCCM(Transfer case control module) > Actuation Test
Front axle engagement actuator
2WD High range indicator
4WD High range indicator
4WD Low range indicator
Transfer case N range indicator
2WD/4WD Synchronizer clutch
2WD/4WD Synchronizer clutch test
Transfer case range [N]
Transfer case range [2WD]
Transfer case range [4WD Low]
Transfer case range [4WD High lo...
TCCM(Transfer case control module) > Data Analysis
Item
Value
Unit
Min
Max
Select
Cancel

Don't Drive ! IG.ON, Gear [N]

* 4WD High range indicator

* Fault codes in other modules can stop shifts from Hl to how + vise aversa.

# NOTES

**Section iv**

# Concentric Clutch Cylinders

**CONTENTS**

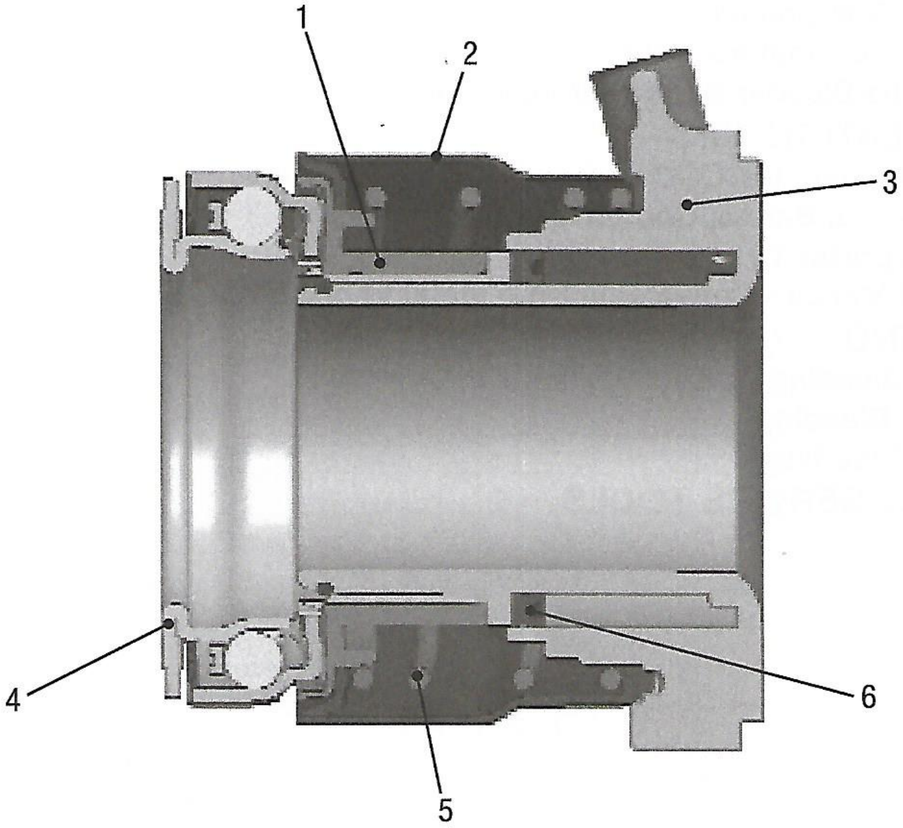
| | |
|---|---|
| INTRODUCTION | 76 |
| Vibration Dampeners | 77 |
| Peak Torque Limiters | 77 |
| Loosen the Bleeder Screw before installing | 78 |
| INSTALLATION TIPS | 78 |
| Bench Bleeding the CCC | 78 |
| Holden Astra, Barina, Combo and Tigra | 79 |
| VW Transporter T4 | 79 |
| Ford and Mazda - Conversion from metal to plastic CCC | 79 |
| BLEEDING | 80 |
| Vacuum Bleeding | 80 |
| Pressure Bleeding | 80 |
| Reverse Bleeding | 80 |
| SPECIAL SERVICE TOOLS | 81 |
| NOTES | 82 |

## INTRODUCTION

The design and implementation of the Concentric Clutch Cylinder (CCC) is one of those designs that makes perfect sense for vehicle manufactures but when you experience a failure of the hydraulic cylinder the technician is left wondering why the cylinder isn't mounted to the outside of the clutch housing, like they were in the good ol' days...

The facts are:

- The CCC removes the three pivot points of a clutch fork system
- This reduces friction, lightening the pedal force required
- Less wear points
- Reduced noise



| Components of a Concentric Clutch Cylinder | | | |
|---|---|---|---|
| 1 | Piston | 2 | Dust Boot |
| 3 | Housing | 4 | Release Bearing |
| 5 | Preload Spring | 6 | Seal |

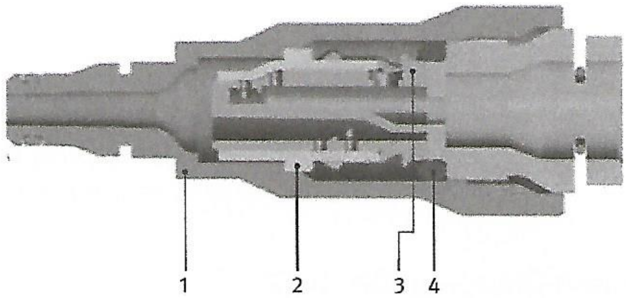
## INTRODUCTION continued...

There are two additional components attached to the CCC but they are not fitted to all vehicles:

- Vibration Dampener
- Peak Torque Limiter (AKA: Clutch Delay Valve)

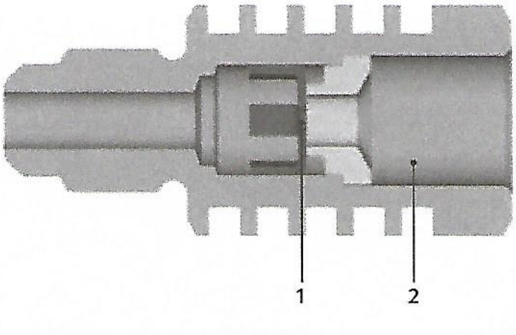
**Vibration Dampeners**
These devices are fitted in-line between the Clutch Master Cylinder and the CCC. They absorb vibrations and prevent them travelling back to the pedal.

* Important.



| Components of a Vibration Dampener | | | |
|---|---|---|---|
| 1 | Housing | 2 | Element |
| 3 | Retainer | 4 | O-Ring |

**Peak Torque Limiters**
These devices are also fitted in-line and work by restricting the fluid flow out of the CCC. This is a safety device to prevent damage to the clutch and Dual Mass Flywheel in the event of the clutch being released too quickly.



| Components of a Peak Torque Limiter | | | |
|---|---|---|---|
| 1 | Faceplate | 2 | Housing |

* Brake fluid flushes are important to prevent faults in these items

## INSTALLATION TIPS

Replacement procedures vary between manufacturers. The vast majority state that the CCC must be replaced whenever the clutch is replaced (and we at Auto-Tech would not recommend otherwise). There are some manufacturers (Nissan is one that we are aware of) that also state that CCC must be replaced whenever the transmission is disconnected from the engine.

**Loosen the Bleeder Screw before installing**

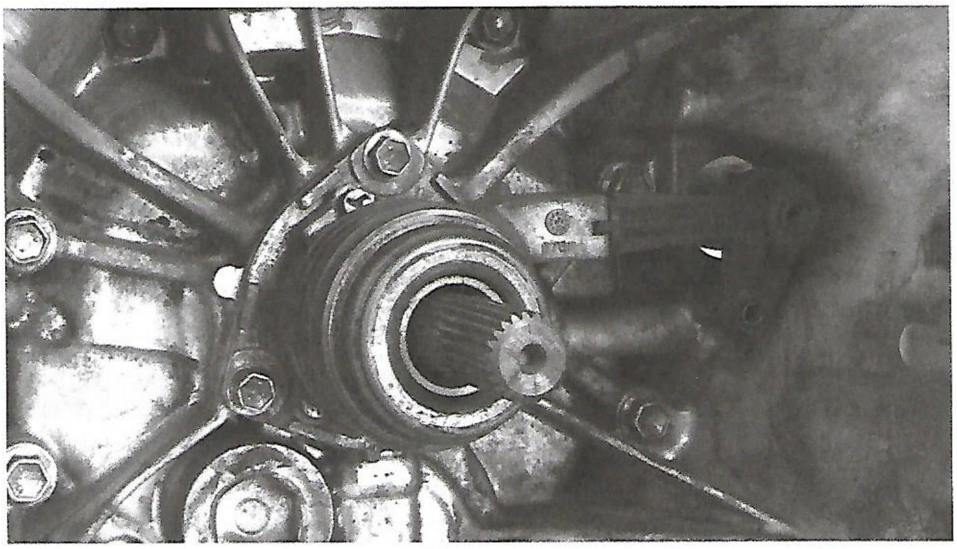
Another tip is to loosen the bleeder screw and refit finger tight. Many of the CCC's come fitted with a knurled bleeder that is opened without tools. Sometimes there is limited space and if the bleeder is over tightened it can be near impossible to loosen.

⚠ *Caution:* *There have also been reports of the bleeder valve snapping off due to over tightening at the factory, resulting in a transmission out rework!*

**Bench Bleeding the CCC**

Many of the CCC's have only one fluid connection going into the cylinder and it is often not at the highest point. This makes bleeding the air from the CCC very difficult after installation. To make bleeding easier once installed follow this procedure:

1. Connect a pipe to the CCC and place the end of the pipe in a clean container of brake fluid (correct spec of course)
2. Gently slide the released bearing back against the preload spring and let it slowly return
3. Repeat while holding the point where the pipe comes out of the housing as close as possible to vertical and until no air is expelled with the fluid
4. Remove the pipe and instal the CCC as per manufacturers recommendations.



*The CCC of a VE V6 Commodore*

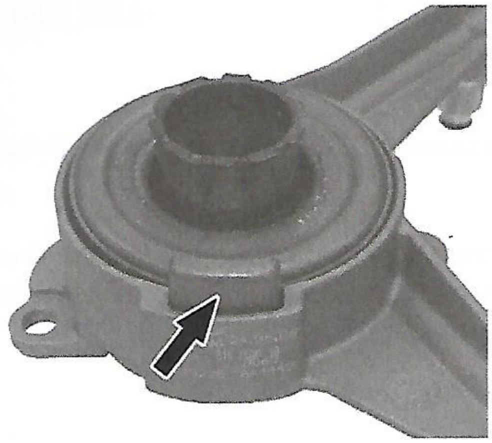
## INSTALLATION TIPS continued...

**Holden Astra, Barina, Combo and Tigra**

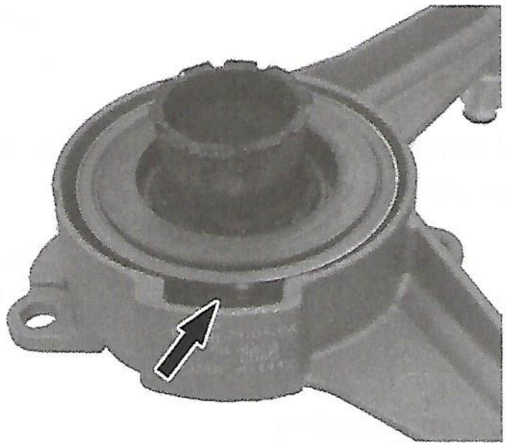
1. Ensure that a new o-ring is fitted between the CCC and the front of the gearbox.
2. Do NOT remove the transportation clip from the new CCC until it is fitted to the gearbox, failure to follow this step will cause the CCC to fall apart.

**VW Transporter T4**

The CCC for the T4 has a removable release bearing. It must be installed correctly!



*Incorrect*



*Correct*

**Ford and Mazda - Conversion from metal to plastic CCC**

Some Ford and Mazda models have the original aluminium CCC replaced with a plastic assembly. This change may require the holes in the clutch housing to be enlarged slightly.

*Superseded CCC*

*New CCC*

## BLEEDING

Always check the manufacturers preferred bleeding procedure. CCC's are notorious for being difficult to bleed and the manufacturers method is often the most effective.

*Note:*

*The most important precaution in bleeding a CCC is to make sure that only slow pedal movements are made. Using a hand to depress and release the pedal is advisable.*

*Aggressive bleeding will result in aerated fluid and a poor clutch pedal!*

If the manufacturers procedure is proving unsuccessful, the following procedures may be of assistance.

*Caution:*

*Some manufacturers state specifically not to use certain methods, if that is the case these warnings must be observed!*

**Vacuum Bleeding**
Vacuum Bleeding draws a greater volume of fluid than manual bleeding without the risk of aerating the fluid. Use a vacuum bleeding kit to ensure for this procedure.

**Pressure Bleeding**
Some manufacturers (such as VW Group) recommend pressure bleeding. A pressure of 2 Bar is applied to the reservoir, then the bleeder is opened while the pedal is actuated by hand.

**Reverse Bleeding**
Use a syringe and 4mm hose or a reverse bleeding kit to force fluid backwards, this method is usually unsuitable for final bleeding as it pushes air back towards the Master Cylinder and it needs to escape. However, it has proven successful in dislodging a stubborn air lock!

# SPECIAL SERVICE TOOLS

| Name | Part Number |
|---|---|
| Repco Mechanical Vacuum Pump | RTT1071 |
| Sidcrome Pneumatic Vacuum Bleeding Kit | SCMT70855 |
| Air Boy Pneumatic Vacuum Bleeding Kit | 124143100 |
| Mityvac Pressure Bleeding Kit | MV6840 |

# NOTES

### Section v

# Pull Type Clutches

## CONTENTS

INTRODUCTION 84
Class 1 85
Class 2 85
Class 3 85
DESIGN 86
REMOVING AND INSTALLATION 87
Subaru WRX STI 88
Hyundai and Kia 90
NOTES 92

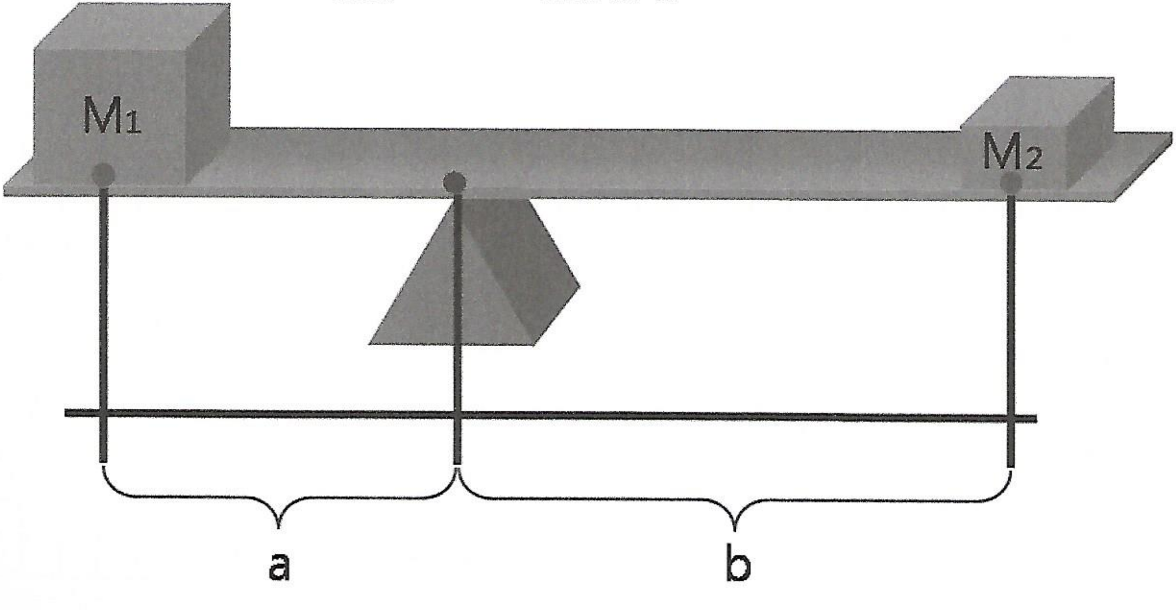
# INTRODUCTION

MADE IN GERMANY
8 000 0530
3482 000 172
127

*Typical Pull Type Clutch assembly with the Release Bearing attached to the Diaphragm Spring*

The benefits of a Pull Type clutch are quite straight forward and are explained by the Law of Levers, which states the relationship between weight and distance from a fulcrum.

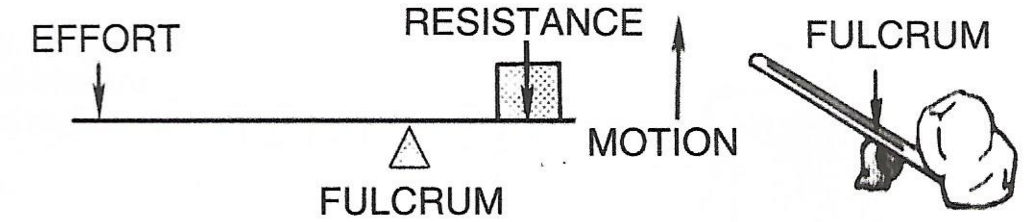
$$M_1 \times a = M_2 \times b$$



## INTRODUCTION continued...

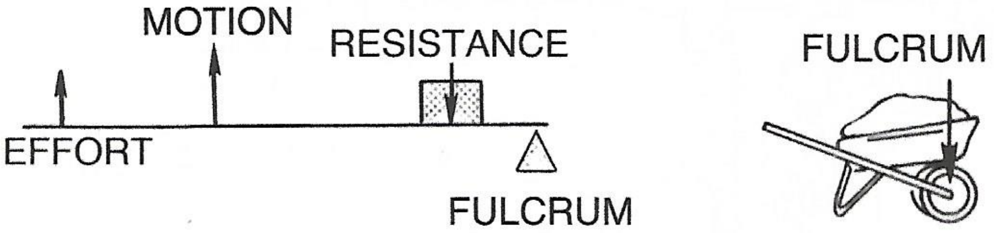
There are 3 types of levers:

**Class 1**
A class 1 lever has the fulcrum between the effort and the resistance.


EFFORT
RESISTANCE
MOTION
FULCRUM
FULCRUM

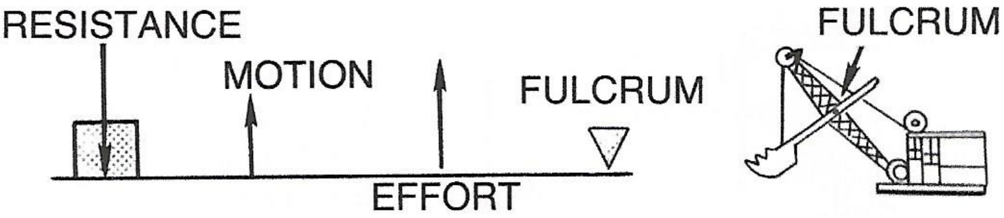
*This is operation of a push type clutch*

**Class 2**
A class 2 lever has the resistance between the effort and the fulcrum.


MOTION
RESISTANCE
EFFORT
FULCRUM
FULCRUM

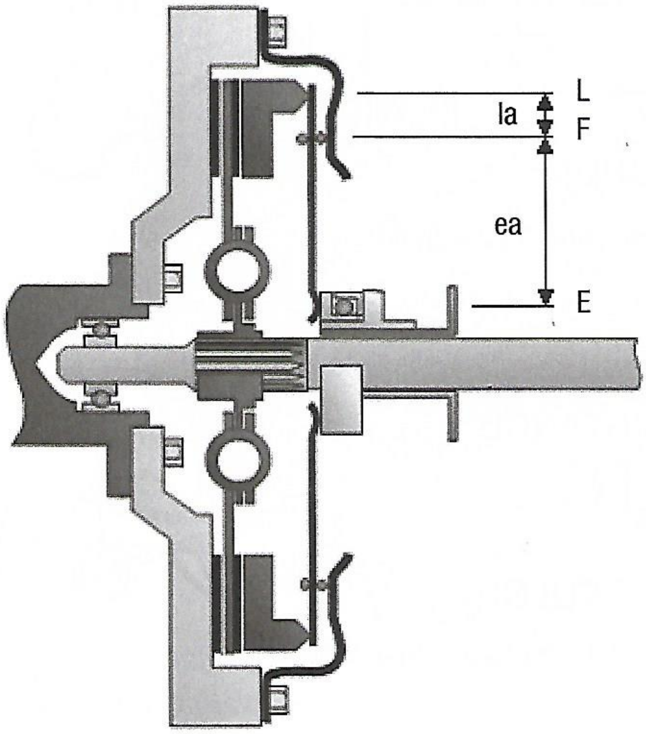
*This is the operations of a pull type clutch.*

**Class 3**
A class 3 lever has the effort between the resistance and the fulcrum.


RESISTANCE
MOTION
FULCRUM
EFFORT
FULCRUM

## DESIGN

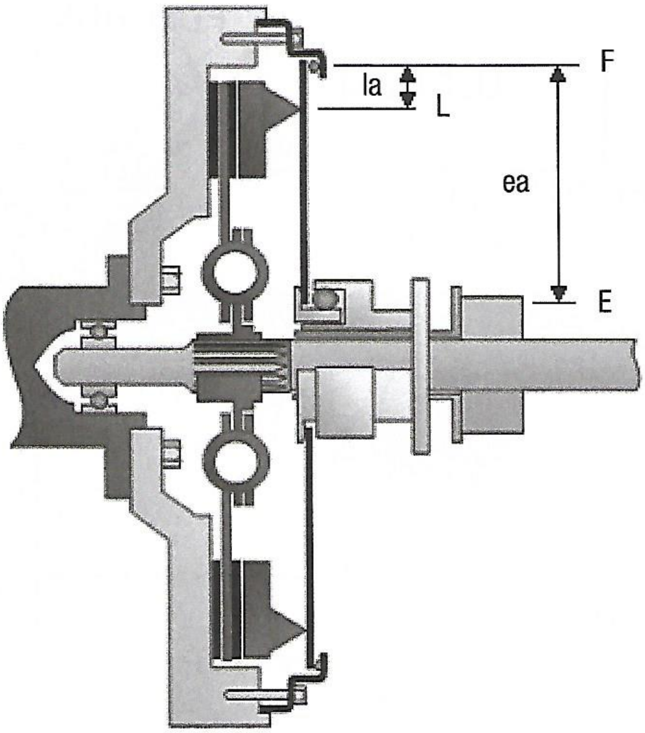
As a general rule, the pull type clutch provides a 30% advantage over the push type. This can be 30% less effort with the same clamping force, 30% more clamping force with the same pedal or a balance between these. The following diagrams show how the mechanical advantage is gained



L = Load
F = Fulcrum
E = Effort
la = Load Arm
ea = Effort Arm
ma = Mechanical Advantage

la = 2.6cm
ea = 10cm
ma = 3.85:1

*Push Type Clutch*



L = Load
F = Fulcrum
E = Effort
la = Load Arm
ea = Effort Arm
ma = Mechanical Advantage

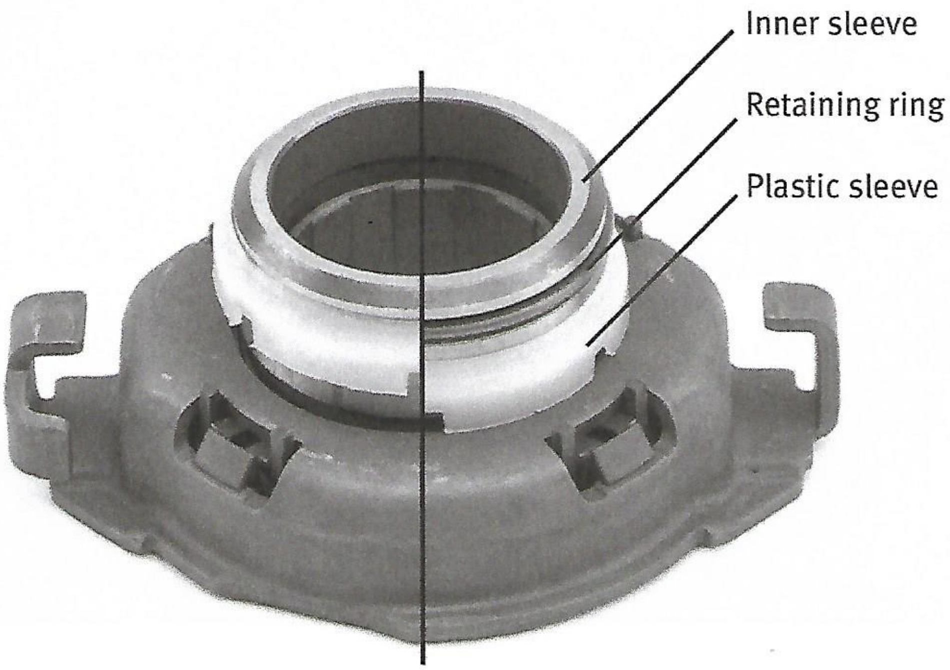
la = 2.6cm
ea = 11.85cm
ma = 4.56:1

*Pull Type Clutch*

## REMOVING AND INSTALLATION

The main disadvantage of a pull type clutch configuration is servicing. The release bearing must slide on the gearbox front bearing retainer, yet must be attached to the diaphragm spring. This means that all pull type clutched vehicles require a special procedure usually to detach the clutch fork from the release bearing.

Virtually all systems use a Release Bearing with a self aligning locking ring that engages after the gearbox has been installed. Many designs now use a plastic guide to make aligning and engaging the locking ring easier.



*Plastic sleeve in the install position (left) and the plastic sleeve in installed position (right)*

The procedures for all vehicles are based on the same principles:

- For removal, the Release Fork must be disengaged to allow the Release Bearing to come out with the Clutch Cover
- For installation, the Release Bearing and Fork are fitted to the Gearbox. Once the gearbox is installed the Release bearing is located and seated into the receiver by applying hand force to the Release Fork in the opposite direction to the Slave Cylinder.

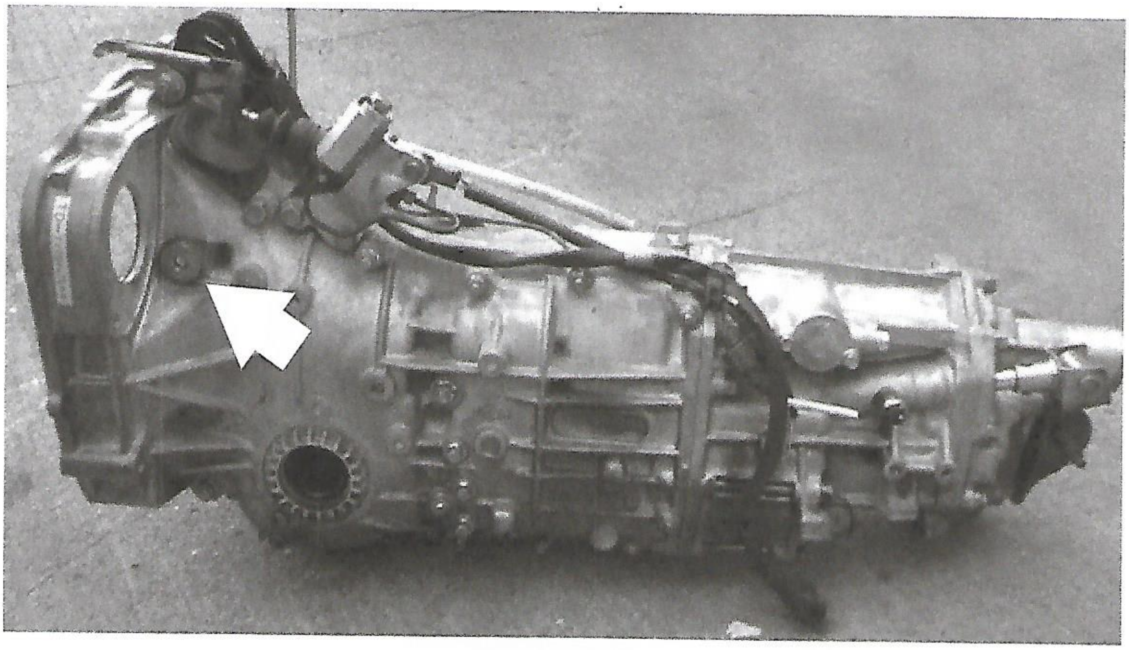
## REMOVING AND INSTALLATION continued...

**Subaru WRX STI**

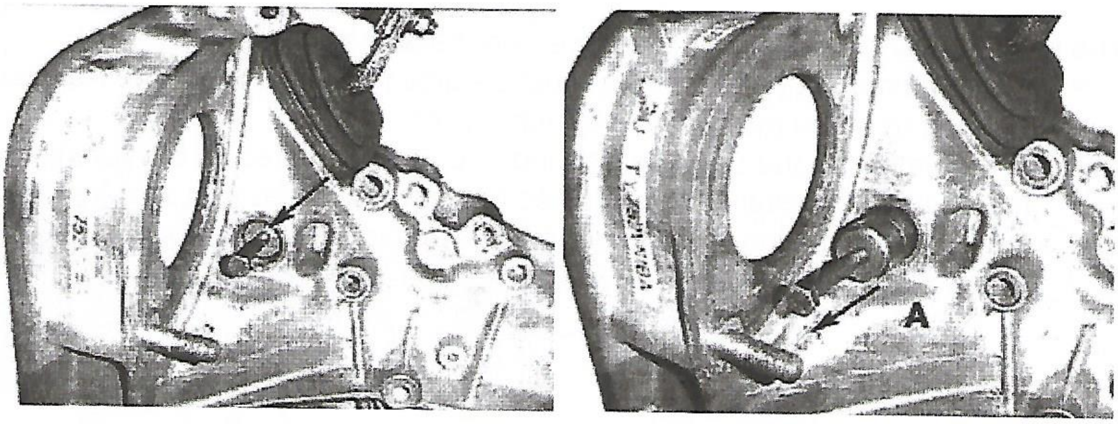
To achieve the greater clamping loads required for the high powered STi, Subaru adopted a pull type clutch for these models. The pull type clutch has 930 kilograms of force (kgf) as opposed to 760kgf on the standard WRX.

Removing the gearbox

1. Remove the blanking plug from the upper left side of the Clutch Housing with a 10mm allen key/bit

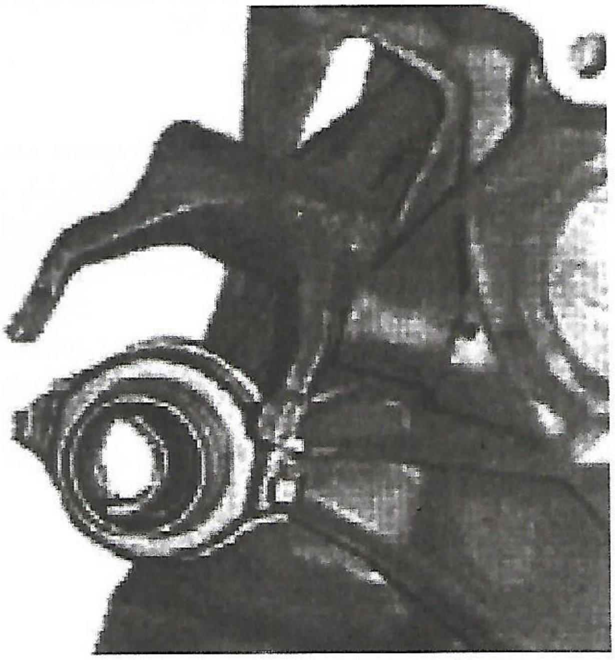


2. Using a 6mm bolt draw the Release Shaft from the Clutch Housing



## REMOVING AND INSTALLATION continued...

3. Lift the release fork until it comes free of the release bearing and set aside



Installing the gearbox

*Caution:* *DO NOT attach the Release Bearing to the Diaphragm Spring, In many circumstances it cannot be removed without damage!*

1. Fit the Release Bearing to the front of the Gearbox and install the Release Fork
2. Fit the Release Shaft and blanking plug
3. Fit the Clutch and reinstall the Gearbox
4. Using firm hand force, engage the Release Bearing into the receiver by pushing in the opposite direction to the Slave Cylinder. A clack noise should be heard and the free play in the Release Lever should be reduced

## REMOVING AND INSTALLATION continued...

**Hyundai and Kia**

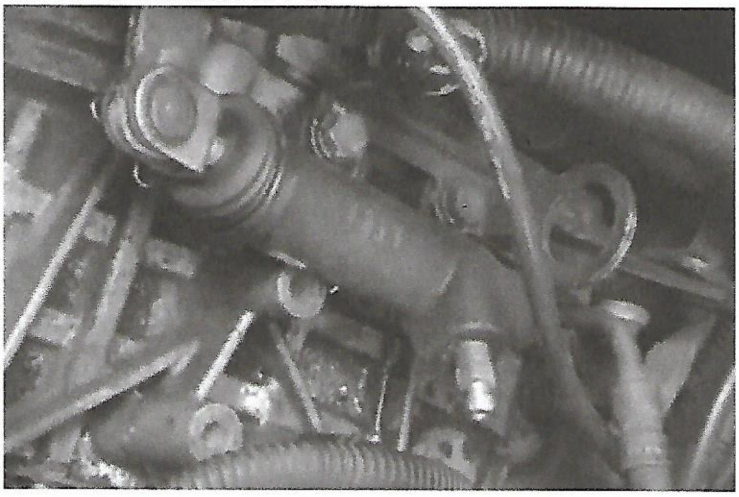
Most of the Hyundai and Kia models built between 1995 and 2007 utilise a pull type clutch.

Identify

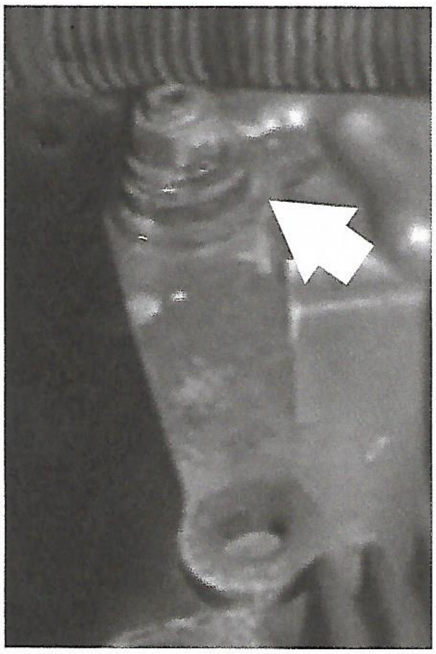
You can identify if a Pull type clutch is in use by the Clevis Pin that is used attach the Slave Cylinder to the Release Fork.

Removal

1. Remove the Clevis Pin



2. Undo the nut that attaches the Release Lever to the Release Fork



3. Remove the Release Lever from the Release Shaft
4. This will now allow the Release Fork to rotate far enough to allow the Release Bearing to come out with the Clutch Assembly

## REMOVING AND INSTALLATION continued...

Install

*Caution:* *DO NOT attach the Release Bearing to the Diaphragm Spring, In many circumstances it cannot be removed without damage!*

1. Fit the Release Bearing to the front of the Gearbox and install the Release Fork
2. Fit the Release Lever (it has a master spline and will only fit in one position)
3. Fit the Clutch and reinstall the Gearbox
4. Using firm hand force, engage the Release Bearing into the receiver by pushing in the opposite direction to the Slave Cylinder. A clack noise should be heard and the free play in the Release Lever should be reduced
5. Refit the Slave Cylinder and Clevis Pin.

# NOTES

### Section vi

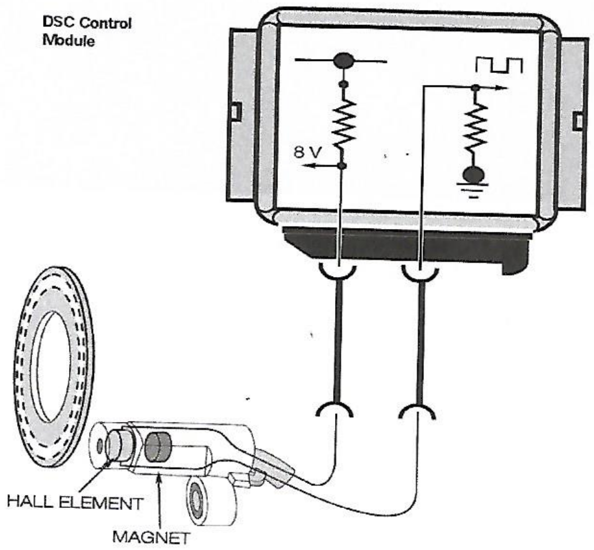
# Two Wire Hall Sensors

## CONTENTS

DESIGN 94
FUNCTION 96

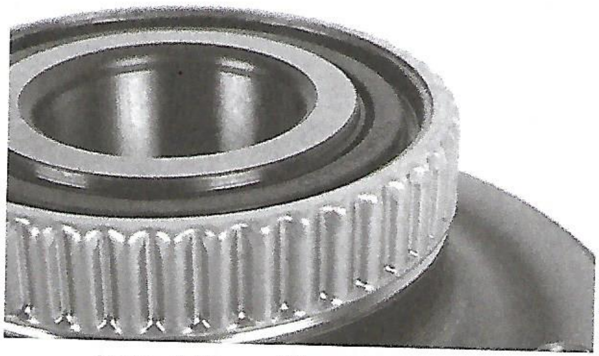
## DESIGN

Two Wire Hall Sensors have caused some confusion for technicians since they first made an appearance on the E38 and E39 BMW's in the mid 1990's. In the mid 2000's Toyota started replacing their Two Wire Inductive Wheel Speed Sensors with Two Wire Hall Type Sensors.

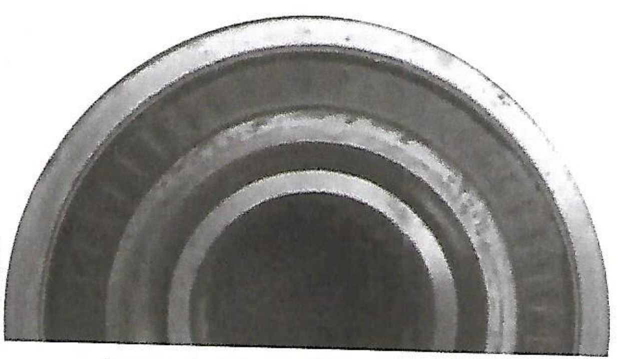


*BMW's schematic showing 8 Volt reference and pull up resistor circuit*

The design of the Two Wire Hall Sensor can use a traditional trigger wheel or a magnetic trigger wheel. The latter is often integrated into the wheel bearing seal.



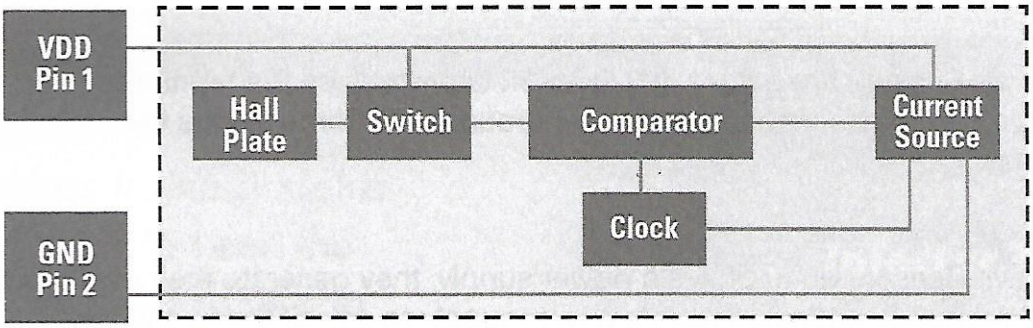
*Typical Trigger Wheel (reluctor)*



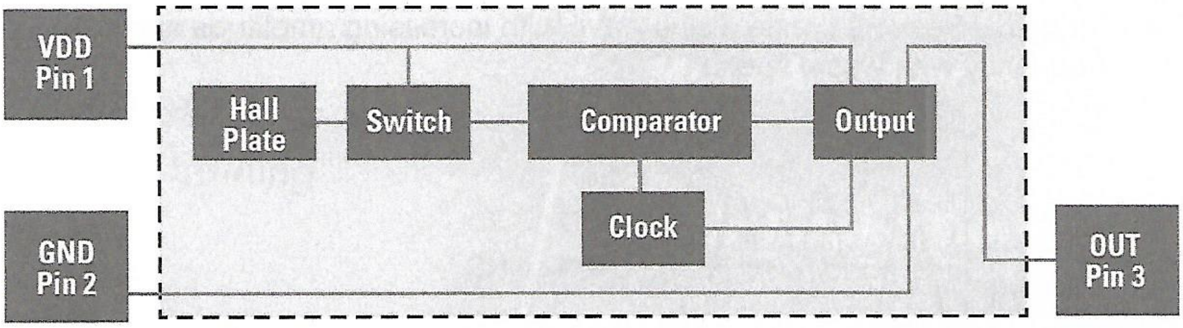
*Magnetic Trigger Wheel (Encoder)*

## DESIGN continued...

Like all Hall Effect sensors, the two wire variant contains internal circuitry which includes a comparator that processes the signal and outputs it as a square wave with fixed amplitude and variable frequency.


VDD Pin 1
GND Pin 2
Hall Plate
Switch
Comparator
Current Source
Clock

*Internal Circuitry of a Two Wire Hall Effect Sensor*


VDD Pin 1
GND Pin 2
Hall Plate
Switch
Comparator
Output
Clock
OUT Pin 3

*Internal Circuitry of a Three Wire Hall Effect Sensor*

# FUNCTION

A visual inspection of a Wheel Speed Sensor will not provide anything to identify if the Sensor is a Two Wire Inductive or Two Wire Hall and many of the factory manuals do not state the sensor type or provide a waveform diagram. There are however a few clear differences once you start testing the components.

Resistance:

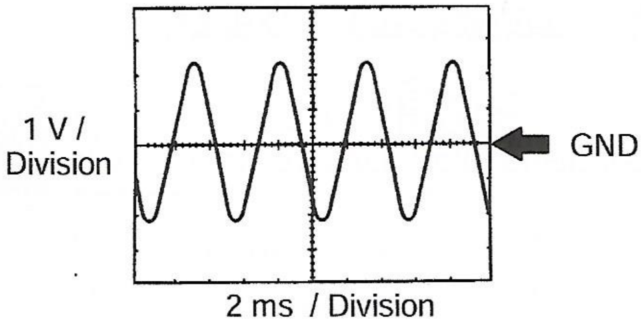
- Inductive Sensors are generally 0.5k to 3k Ohms across the terminals
- Two Wire Hall Sensors are much lower around 100 Ohms across the terminals

Voltage:

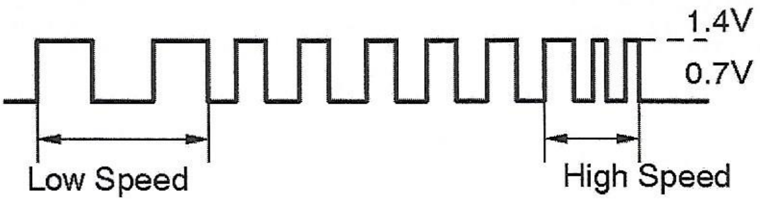
- Inductive Sensors do not have a power supply, they generate their own signal
- Two Wire Hall Sensors will have a power supply to one of the two wires (BMW use 8 Volts, Toyota use Battery Volts)

Waveform

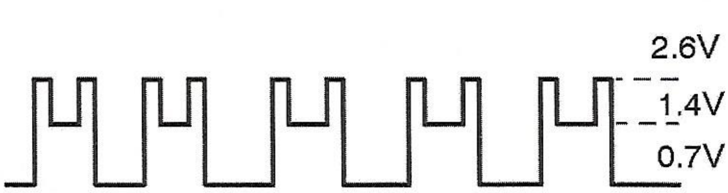
- Inductive Sensors create a sine wave with increasing amplitude and frequency with wheel speed



- Two Wire Hall Sensors will produce a square wave signal with fixed amplitude and increasing frequency with vehicle speed



- Two Wire Hall Sensors will usually produce either no signal in reverse or a different signal in reverse



Repco AUTO TECH

**ALL NEW TOPICS IN EVERY COURSE**

# AUTO-TECH MASTERCLASS

Training for Master Technicians

## 2018.1

Masterclass training nights are designed to keep the modern technician ahead of the industry by teaching essential diagnostic techniques for many vehicle systems.

Attendees will receive:

- Instructor led training
- certificate
- light supper
- technical manual

**Find out more or book online at**

**www.autotechstore.com.au**

**Injector Testing with Current Clamps**

**Mass Air Flow Meter Testing**

**Air Intake Control Systems**

**CAN Bus Part 2**

**Diagnostics with Fuel Trims**

**Variable Compression Ratio Engines**

**NEW**

**Commencing Feb 2018**

## DIESEL & PETROL ENGINE MANAGEMENT